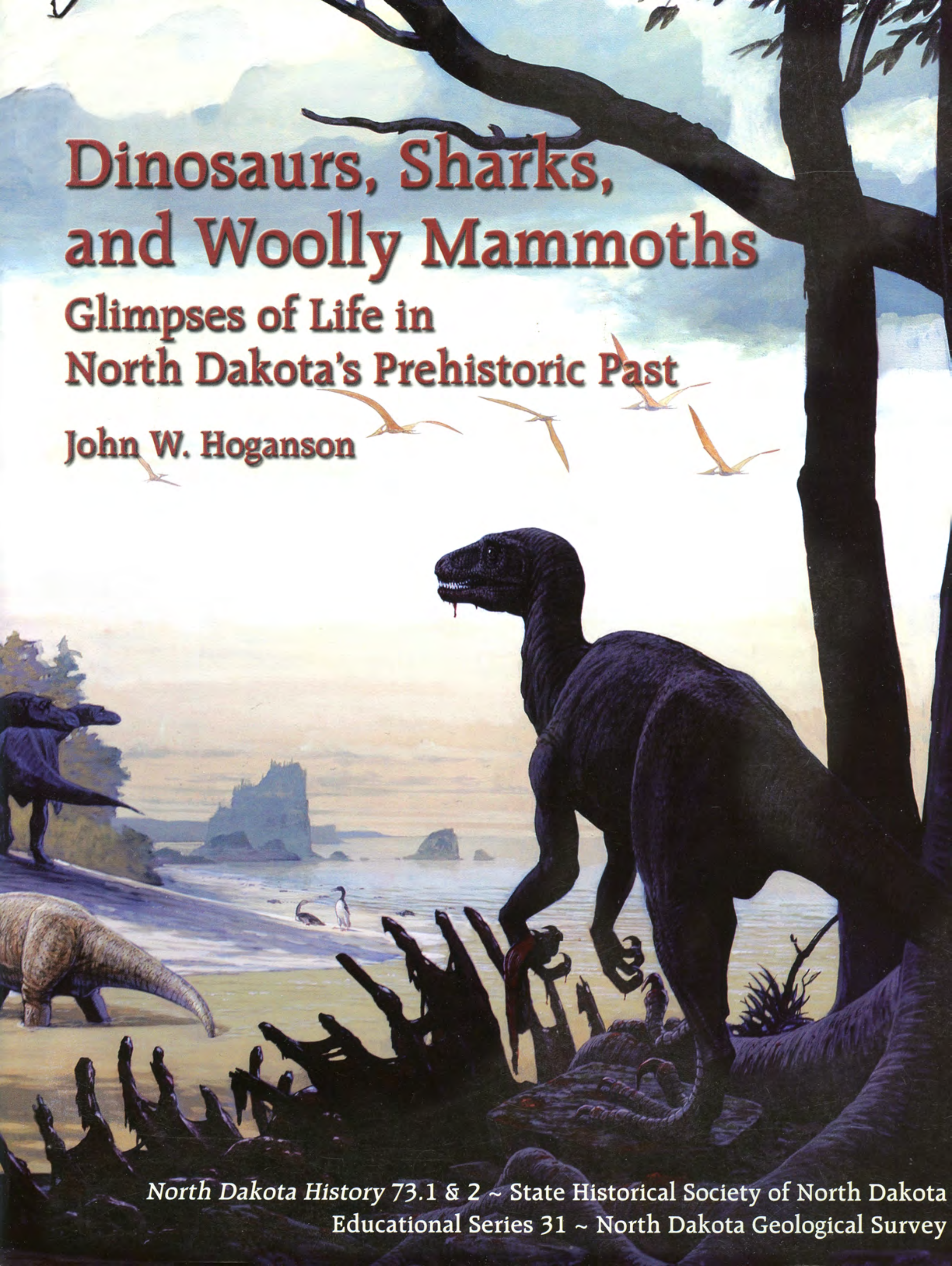
Dinosaurs, Sharks, and Woolly Mammoths

Glimpses of Life in North Dakota's Prehistoric Past

John W. Hoganson



North Dakota History 73.1 & 2 ~ State Historical Society of North Dakota
Educational Series 31 ~ North Dakota Geological Survey

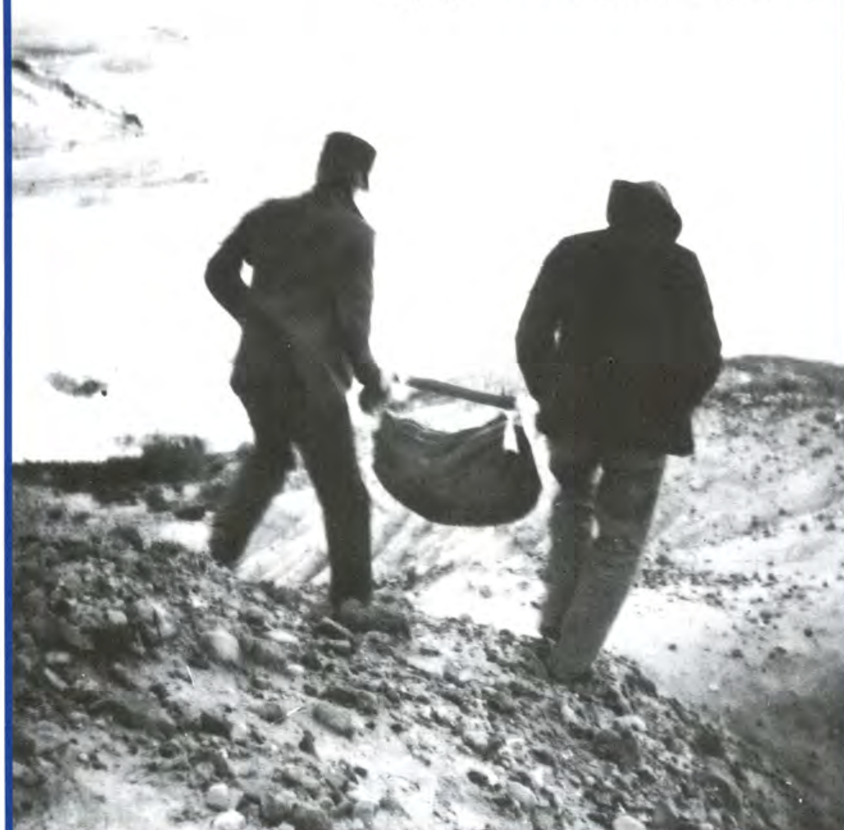
SHSND 0003-043

Douglass identifies this photograph as part of the eastern portion of White Butte, looking eastward, stating that "the Upper, Middle, and Lower White River Beds are here Exposed."

From the Collections...

SHSND 0003-194

Elizabeth Roberts took this photograph during one of Douglass's excavations in the White Butte area. The caption with the image describes it as showing Douglass carrying a skull recovered during his dig.



Cover Image: This mural of the Hell Creek Delta as it may have appeared in North Dakota sixty-five million years ago, as well as the depiction of the Paleocene habitat on page 26, was painted by Geoff Elson for the State Historical Society of North Dakota. Both murals are on display at the North Dakota Heritage Center.

Meriwether Lewis and William Clark were the first to collect fossils in North Dakota for scientific study, although American Indians had been gathering fossils for ornamental jewelry and spiritual effigies for hundreds, perhaps thousands, of years. The petrified wood that Lewis and Clark collected was from the Paleocene (about sixty million years old) Sentinel Butte Formation. It was sent back to President Thomas Jefferson from Fort Mandan in 1805, but the fossil has since been lost. Famous pioneering paleontologists such as Edward Drinker Cope and Ferdinand V. Hayden began prospecting for fossils in North Dakota in the mid- to late 1800s, and large eastern museums and universities have launched fossil collecting expeditions to North Dakota ever since.

In 1905 Earl Douglass was sent to North Dakota to collect fossils for the Carnegie Museum in Pittsburgh. His intriguing geological account of stagecoach, horseback, and buckboard travel to fossil sites at Black Butte, Chalky Buttes, and White Butte (Slope County) and the Little Badlands (Stark County), where he collected remains of the diminutive ancestral horse *Mesohippus* and the hornless rhinoceros *Subhyracodon* from the Oligocene (about thirty million years old) Brule Formation, is in volume 5 of the 1909 *Annals of the Carnegie Museum*. Part of the time he headquartered out of the T.F. Roberts ranch near White Butte. Photographs taken by Mrs. (Elizabeth) Roberts were included in Douglass's 1909 publication. Many of Mrs. Roberts' original photographs, such as those on this page, and several of her cameras are now in the State Historical Society of North Dakota collections at the North Dakota Heritage Center.

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EDITOR'S NOTE

This special paleontology issue of North Dakota History *is a joint effort of the State Historical Society of North Dakota and the North Dakota Geological Survey (NDGS). Written by NDGS paleontologist Dr. John Hoganson, this issue encapsulates a century of paleontological research done in North Dakota and is the first single-source publication to give an overview of life in our state during the past five hundred-plus million years. It also serves as a companion piece to the recently installed* Corridor of Time *exhibit at the North Dakota Heritage Center, where many of the fossils described herein can be viewed.*

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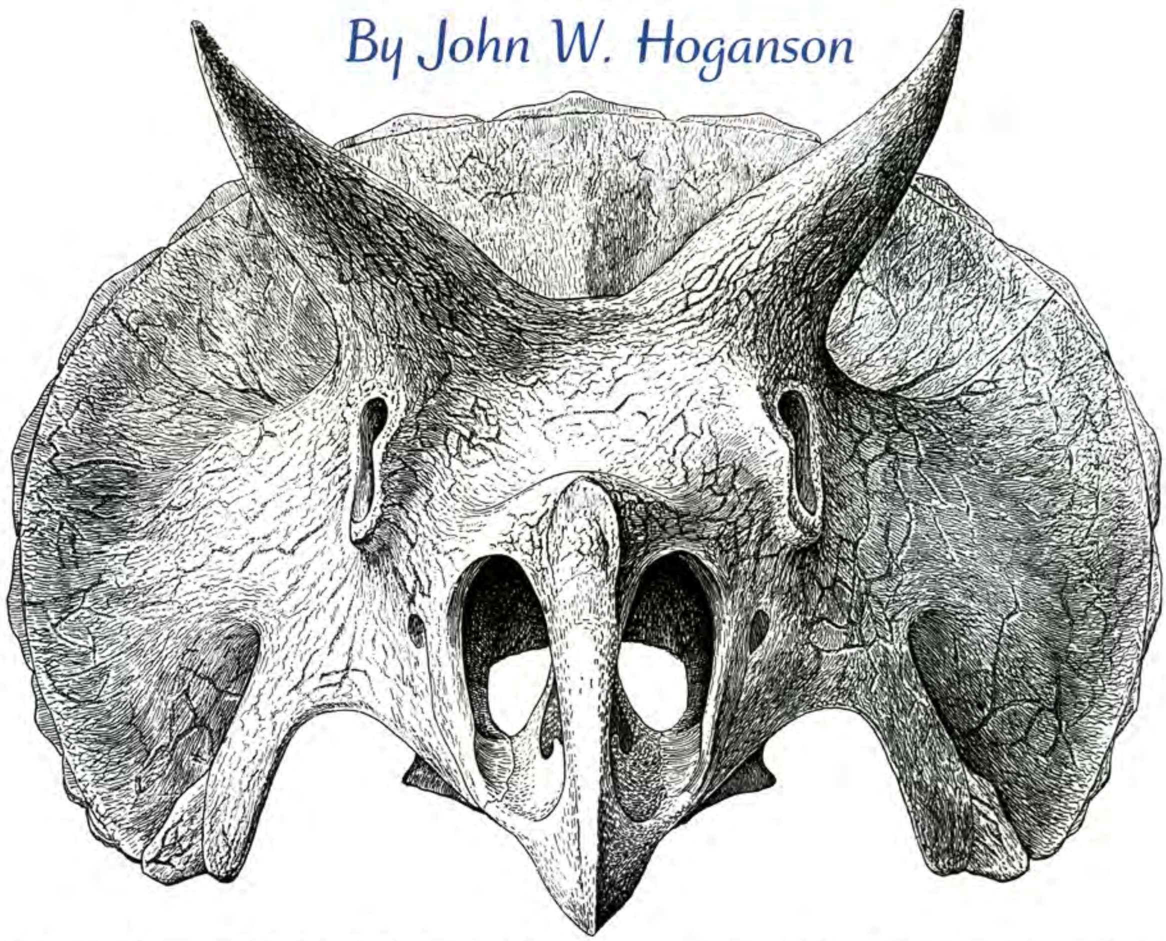
Dinosaurs, Sharks, and Woolly Mammoths: Glimpses of Life in North Dakota's Prehistoric Past

By John W. Hoganson



Drawing of *Triceratops* dinosaur skull, from "The Ceratopsia," by John B. Hatcher, U.S. Geological Survey Monograph 49 (1907)

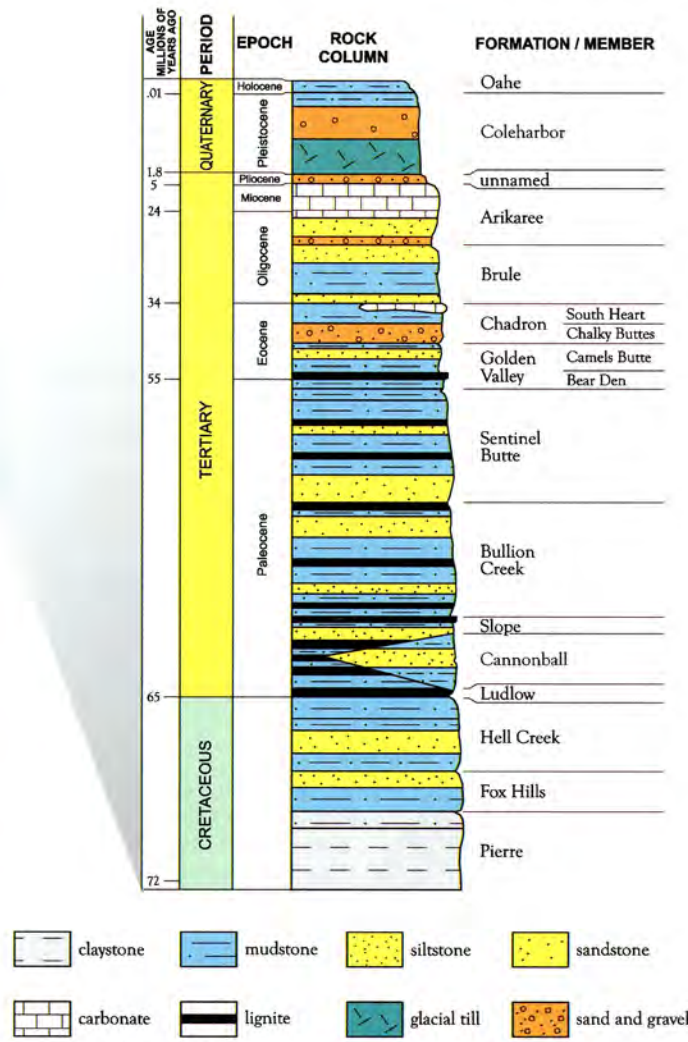
Picture yourself eighty million years ago, swimming in a warm-water ocean with sharks, forty-foot-long sea lizards, giant sea turtles, and fifteen-foot squids where Cooperstown, Walhalla, and McCanna are today; or beachcombing along a delta shoreline near present-day Bismarck sixty-eight million years ago, with dinosaurs such as Triceratops, Tyrannosaurus rex, *and dromaeosaurs lurking in a forest at water's edge; or, sixty million years ago, canoeing through a swamp inhabited by bald cypresses, magnolias, palm trees, fifteen-foot crocodiles, and primate-like mammals in the area of today's Medora, Watford City, and Williston. Thirty million years ago you might have gone on safari through an African-like savanna around modern-day Dickinson and Amidon, surrounded by rhinoceroses, camels, two-foot-tall horses, and saber-toothed cats; go back twelve thousand years, and you might have snowshoed across a tundra plain near today's Fort Yates, Fargo, Minot and Grand Forks, warily watching for woolly mammoths and giant ground sloths. These glimpses of life in North Dakota at different times in our geologic past are based on the state's fossil record. They are explored in the exhibits of the North Dakota Heritage Center, where most of the fossils in this issue are on display, and in the pages of this issue.*

The history of life in North Dakota from the time that monstrous sea creatures inhabited the primordial oceans millions of years ago to the appearance of humans only a few thousand years ago is a fascinating saga. That history is being deciphered by paleontologists through the study of fossils, our primary means of documenting the evolutionary history of past life. Fossils define the kinds of plants and animals that inhabited North Dakota at various times in the geologic past. They also are important indicators of how the region's climates and environments have changed through time.

The most difficult concept for the general public—or, for that matter, students of paleontology—to comprehend is the great span of geologic time, sometimes referred to as "deep time." Earth is considered to be about 4.6 billion years old, and the beginnings of life on Earth are believed to date back about 3.6 billion years. These numbers are small, however, compared to the tens of billions of years cosmologists and astronomers consider in studying events in the universe. It is difficult for humans to conceive of anything that is, say, even a million years old because human experiences are measured in hours, days, months, and years.

Like historical events, paleontological events have little meaning unless they are put into a time perspective. Beginning about 1820, a calendar called the Geologic Time Scale was developed—and is still being refined—that divides the Earth's history into segments of time (eras, periods, epochs) which are most often based on changes in life forms. So, for example, the major time divisions—the Paleozoic, Mesozoic, and Cenozoic Eras—literally mean "ancient life" (Paleozoic), "middle life" (Mesozoic), and "recent life" (Cenozoic). The numerical dates of these time divisions, usually expressed in millions of years, are based on measurements of the radioactive decay of minerals found in rock formations. This is called radiometric dating. The geologic calendar is frequently expressed through the use of a stratigraphic column.

AGE	ERA	PERIOD	FORMATION or GROUP
MILLIONS OF YEARS AGO	CENOZOIC	QUATERNARY	OAHE COLEHARBOR
		TERTIARY	ARIKAREE WHITE RIVER GOLDEN VALLEY SENTINEL BUTTE BULLION CREEK SLOPE CANNONBALL LUDLOW
65	MESOZOIC	CRETACEOUS	HELL CREEK FOX HILLS PIERRE NIOBRARA CARLILE GREENHORN BELLE FOURCHE MOWRY NEWCASTLE SKULL CREEK INYAN KARA
		JURASSIC	SWIFT RIERDON PIPER
		TRIASSIC	SPEARFISH
250	PALEOZOIC	PERMIAN	MINNEKAHTA OPECHE
		PENNSYLVANIAN	BROOM CREEK AMSDEN TYLER
		MISSISSIPPIAN	BIG SNOWY MADISON
		DEVONIAN	BAKKEN THREE FORKS BIRDBEAR DUPEROW SOURIS RIVER DAWSON BAY PRAIRIE WINNIPEGOSIS
		SILURIAN	INTERLAKE
		ORDOVICIAN	STONEWALL STONY MOUNTAIN RED RIVER ROUGHLOCK ICEBOX BLACK ISLAND
570		CAMBRIAN	DEADWOOD
4500		PRECAMBRIAN	



The North Dakota stratigraphic column lists the names of the rock formations that occur in North Dakota and the types of rocks of which they are composed. This list of formations is arranged on the Geologic Time Scale from oldest to youngest in "stratigraphic" order. The geologic time period and age in millions of years for each formation is thereby indicated. For example, the Pierre Formation consists mostly of claystone and was deposited during the Cretaceous Period over seventy million years ago. The Niobrara Formation is older and lies stratigraphically beneath the Pierre Formation, while the Fox Hills Formation is younger and stratigraphically above the Pierre Formation.

Fossils and Fossil Hunters

Fossils, from the Latin *fossilis,* meaning "digging" or "dug up," are remains of plants and animals preserved in the earth. Fossils can be the actual remains, such as shell or bone, or can be traces, such as tracks or burrows. This definition is not as straightforward as it seems because some paleontologists require the remains to be prehistoric—that is, at least around five thousand years old—to be considered fossils, while others include remains from historic times. Objects constructed by humans (pottery, projectile points, buildings, etc.) are termed artifacts, not fossils, and are studied by archaeologists, not paleontologists.

Fossils are not common because when a plant or animal dies most often the remains simply rot away or are scavenged, leaving no trace that it ever existed. This is particularly true for "soft-bodied" animals—creatures such as worms and most insects that do not have a shell or internal skeleton; the remains of these creatures, and most others, must be buried quickly for them to have a chance of becoming fossilized. Also, many forces, particularly weathering, can destroy fossils before they are found. Sadly, our record of life on Earth is very incomplete. It has been estimated that only one percent of all species that ever lived have left a fossil record.[1] It is especially rare to find a complete fossilized skelton of an animal because factors like scavenging and weathering can affect the carcass before it is buried. As the scientist Susan Kidwell once put it, "Life after death is risky." Because of the scarcity of complete or mostly complete skeletons, paleontologists fantasize about finding them. For these reasons, fossils should be viewed as objects of great scientific value. They are an important part of our natural heritage and should be preserved whenever possible for all humankind.

The people who study fossils are known as paleontologists. Paleontology is generally considered a subdiscipline of geology, but it is an interdisciplinary science that blends geology and biology. Paleontologists have extensive training in biology, and many paleontologists have university degrees in the biological sciences. Knowledge of the anatomy, behavior, and habitat preferences of living animals and plants is critical for interpreting the appearances and lifeways of species that are extinct and represented only by fossils.

Paleontologists often collaborate with artists to breathe life into prehistoric animals and plants. Fossils can provide information about the size, shape, musculature, and posture of an animal, all of which aids the artist in rendering an image of the animal. The color of the skin, hide, shell, or feathers is almost never preserved in the fossil record, however, allowing a certain amount of artistic license in creating the final image of the animal. Paintings by several artists of prehistoric animals, plants, and habitats appear throughout this issue.

Photo by John Hoganson

***Triceratops* dinosaur dig west of Marmarth, Slope County, in 2002. A partial skeleton of a *Triceratops* was excavated; rib bones can be seen in the lower right of this picture, and the skull is pictured on page 18. This was a public fossil dig co-sponsored by the North Dakota Geological Survey and USDA Forest Service-Dakota Prairie Grasslands.**

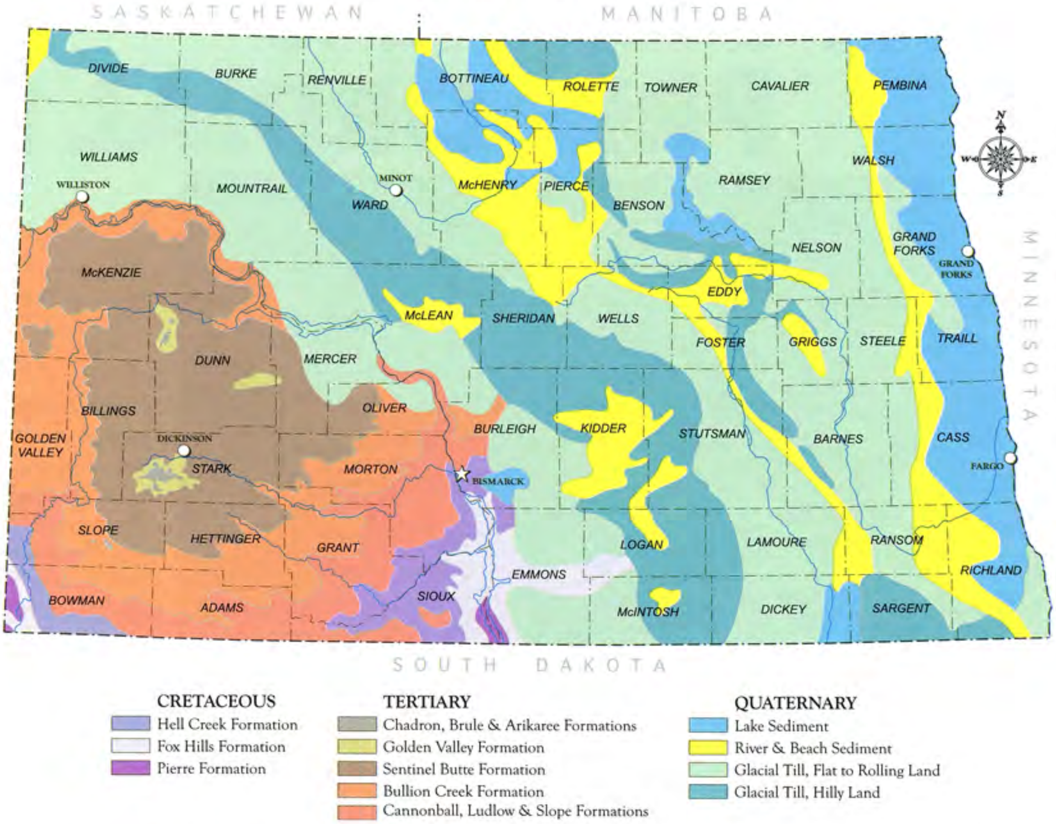
Shrimp burrow
Ophiomorpha
Fox Hill Formation
Bowman County
Length 200 mm
ND 94-134.2

Fossils include not only actual remains like bones, but also traces, such as this burrow (left) in which a shrimp lived about sixty-eight million years ago. Fossils range in size from the massive bones of dinosaurs such as *Edmontosaurus* to remains barely visible to the eye, such as the minute fossil teeth of some sharks. Because shark skeletons are made of cartilage, which does not preserve, these shark teeth are the only clues to one of the most important groups of animals that lived in the ancient oceans of North Dakota. Paleontologists disaggregate the rock in which the teeth are embedded in order to recover these tiny remains.

Shark tooth
Squalus minor
Cannonball Formation
Bowman County
Width 3.4 mm
UND 15823

Actual Size
(3.4 mm)

Geologic Map of North Dakota



Map by Brian R. Austin

Geologists also name the rock formations that were deposited during each geologic time period. The names are based on the geologic location where the best example of the rocks can be seen. Formations are defined by the characteristics of the rocks, such as composition (sandstone, siltstone, mudstone, for example), color, thickness, the kinds of fossils they contain, and many other attributes. The areas where a particular formation appears on the surface can be mapped and plotted on a geologic map. Paleontologists can use these geologic maps to guide them to places where rocks containing particular kinds of fossils may be found. For example, the North Dakota geologic map above shows areas where the rocks known as the Hell Creek Formation surface. (The name of this formation comes from Hell Creek in northeastern Montana, where extensive exposures of the rocks are found.) The stratigraphic column of North Dakota identifies the Hell Creek Formation as having been laid down between sixty-seven and sixty-five million years ago—at the very end of the age of dinosaurs. Paleontologists would therefore expect those areas to have the potential for yielding dinosaur fossils. Knowledge of the location, lithology (rock type), age, and kinds of fossils found in the formations presented on the Geologic Map and Stratigraphic Column of North Dakota has been accumulating since the 1800s, based on research conducted by geologists and paleontologists from North Dakota and many other places. These tools, coupled with reports of past studies, many of which are cited in this issue, provide a basis for the many paleontological investigations that are currently underway in the state. The following glimpses of life in North Dakota's prehistoric past provide a summary of this knowledge accumulated over many decades. The reader should be advised that this knowledge is continually being refined through frequent discovery of fossils of plants and animals that were previously not known to exist in North Dakota. With this in mind, let us take a journey through time beginning about five hundred million years ago, when North Dakota was covered by primordial seas.

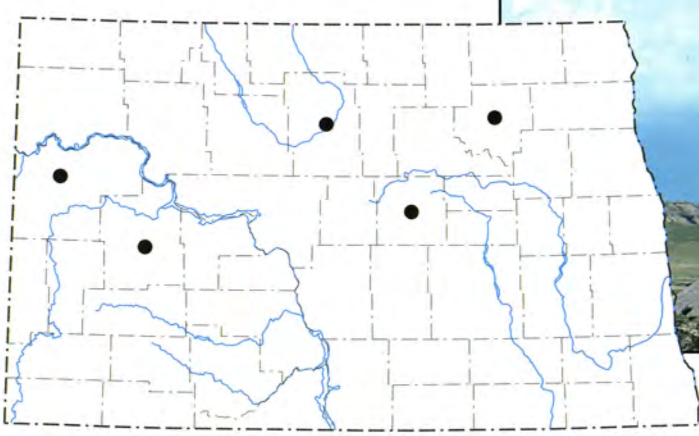
Fossil hunting is by far the most fascinating of all sports. . . . It has some danger, enough to give it zest . . . and the danger is wholly to the hunter. It has uncertainty and excitement and all the thrills of gambling with none of its vicious features. The hunter never knows what his bag may be, perhaps nothing, perhaps a creature never before seen by human eyes. Over the next hill may lie a great discovery! It requires knowledge, skill, and some degree of hardihood. . . . The fossil hunter does not kill, he resurrects. And the result of this sport is to add to the sum of human pleasure and to the treasure of human knowledge."[2]

George Gaylord Simpson, Attending Marvels, *1934.*

NORTH DAKOTA'S PRIMORDIAL SEAS

Diorama courtesy of Smithsonian Institution

North Dakota as it may have looked about 450 million years ago. The oldest fossils found in North Dakota are frequently discovered by oil exploration rigs like the one below. The locations of the drilling cores illustrated in this section are identified on the map.



Map by Brian R. Austin

Photo by Ed Murphy

The oldest exposed rocks containing fossils in North Dakota that paleontologists can explore are only about eighty-five million years old, and yet the fossil record of life in the state extends back to the Cambrian Period, over five hundred million years ago. This early record of life is revealed by fossils found in oil well cores (cylinders of rock) and cuttings (rock fragments) brought to the Earth's surface, often from several thousand feet, during exploration for petroleum. These are examined by geologists, to help determine if petroleum is in the rocks. The oldest fossils found in North Dakota are from the late Cambrian and early Ordovician (approximately five hundred million years old), recovered from depths of about fourteen thousand feet (4,200 meters) in the Deadwood Formation in Williams County. They are the microscopic tooth-like remains of the enigmatic, wormlike marine animals called conodonts, believed by many to be early vertebrates.[3] Brachiopods (clam-like animals), trilobites, echinoderms (sea lilies), gastropods (snails), and trace fossils (burrows created by unknown organisms) have also been found in Deadwood Formation cores.[4]

During most of the Paleozoic and Mesozoic Eras, from about 570 million until about sixty-five million years ago, North Dakota was covered by warm, shallow seas bordered by marine lagoon and estuary habitats, in some cases similar to areas in the Caribbean near the Bahamas today.[5]

During this time there were also periods when North Dakota was dry land. We know that seas covered the state during the Paleozoic because the types of rocks—mostly limestone, dolomite, shale, siltstone and evaporates—and fossils indicate marine environments. Most of the fossils are remains of invertebrate animals such as gastropods, bivalves (clams), brachiopods, corals, stromatoporoids (sponge-like animals), trilobites, and echinoderms. The Devonian-Mississippian Bakken Formation (about three hundred million years old) has yielded many of these fossils. Approximately fifty species of invertebrates, plants, trace fossils, and conodonts have been discovered in that formation.[6] Rarely, remains of vertebrates other than conodonts are found, particularly fish such as those recovered from the Pennsylvanian Tyler Formation by J.C. Grenda and from the Devonian Duperow Formation by J.W. Hoganson.[7] In some cases fossils are abundant enough to allow us to reconstruct what the animal communities were like in these primordial seas.

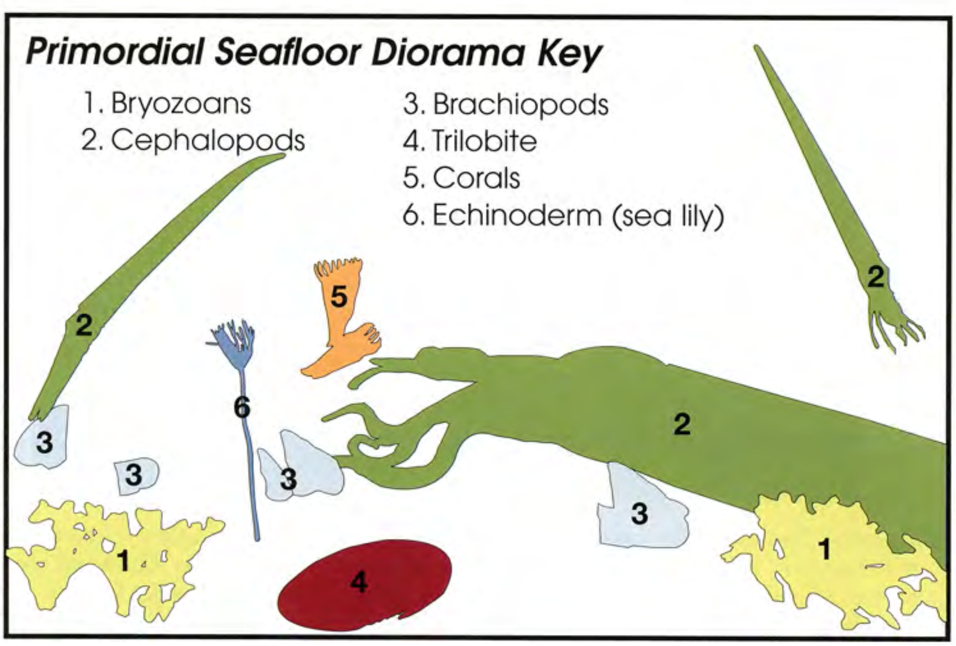
Some of the oldest fossils discovered in North Dakota are illustrated below. The Ordovician brachiopods are about 450 million years old. Depth from which drilling cores were recovered is indicated.

Stromatoporoid (sponge-like animal)
Devonian
Duperow Formation
4,402 feet
Wells County
Width 9 cm
NDGS 207

Sea lily stem fragments
Devonian
Winnipegosis Formation
5,283 feet
McHenry County
Width 7.5 cm
NDGS 5283

Corals
Mississippian
Madison Group
9,290 feet
Dunn County
Length 16.9 cm
NDGS 607

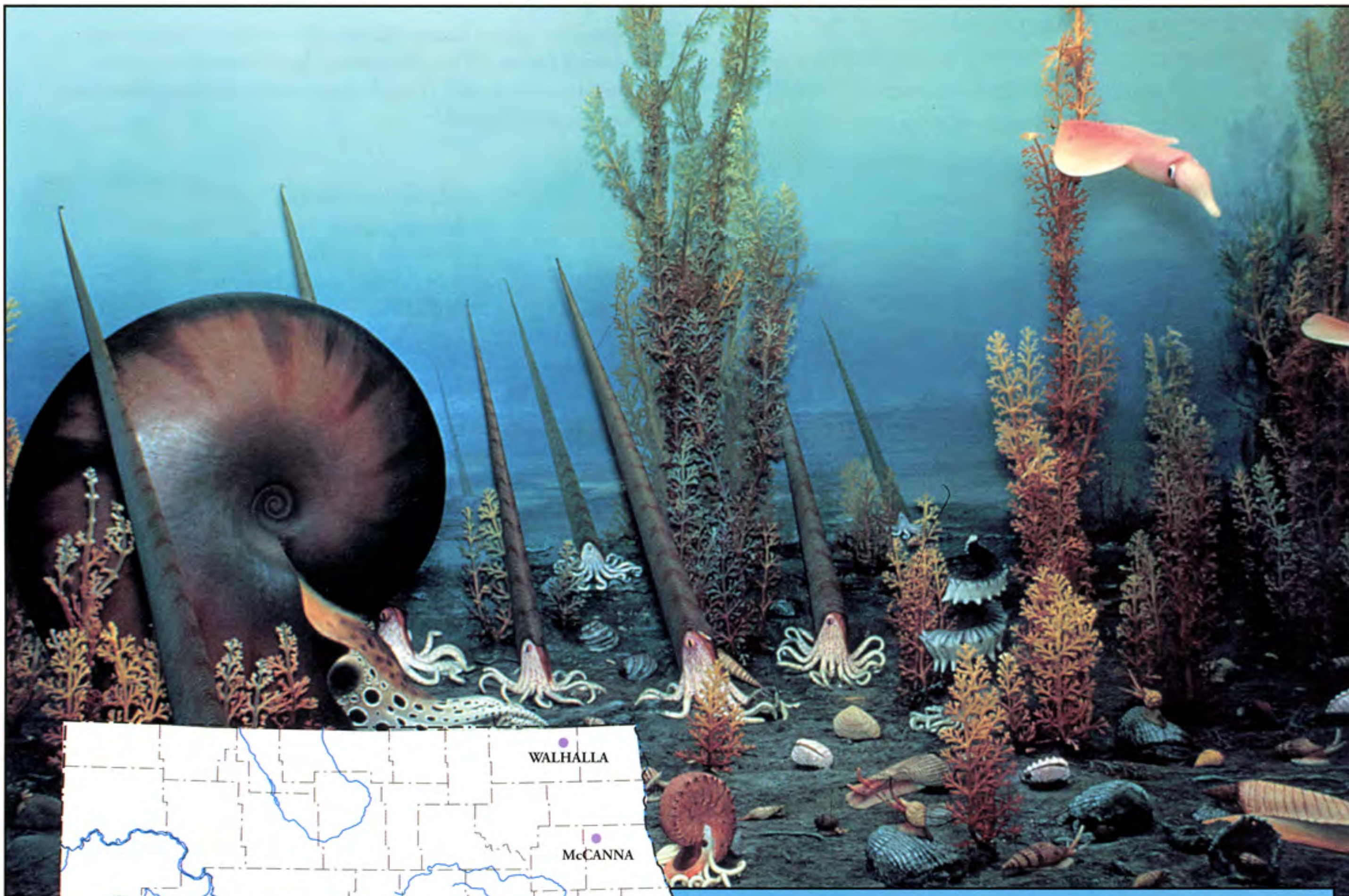
Gastropod (snail)
Mississippian
Madison Group
9,617 feet
McKenzie County
Length 12 cm
NDGS 2667



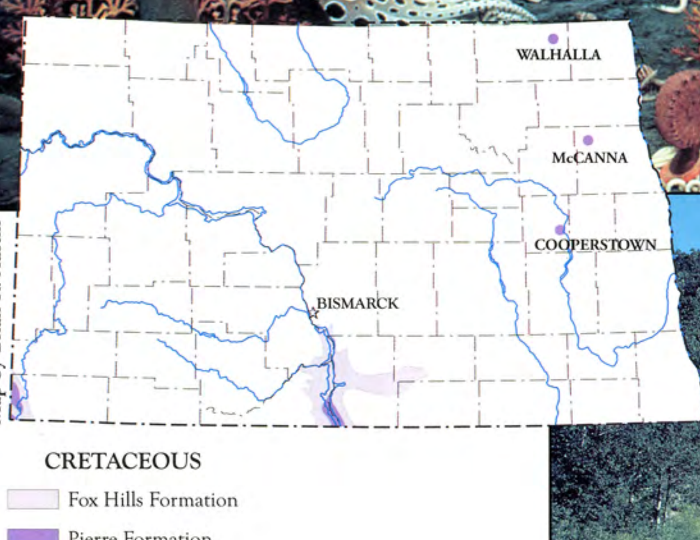
Key by Robin Pursley

Brachiopods (clam-like animal)
Ordovician
Stony Mountain Formation
2,456 feet
Ramsey County
Width 10 cm
UND A2602.241

NORTH DAKOTA'S CRETACEOUS UNDERWATER WORLD



Courtesy of Smithsonian Institution



Map by Brian R. Austin

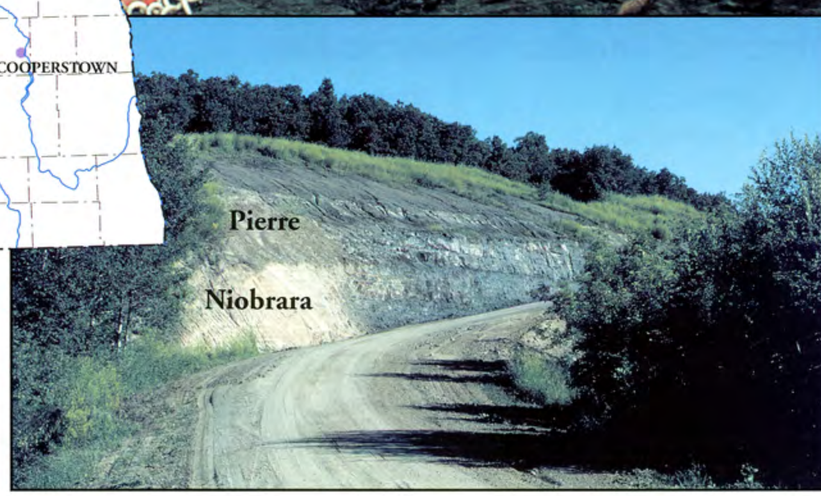
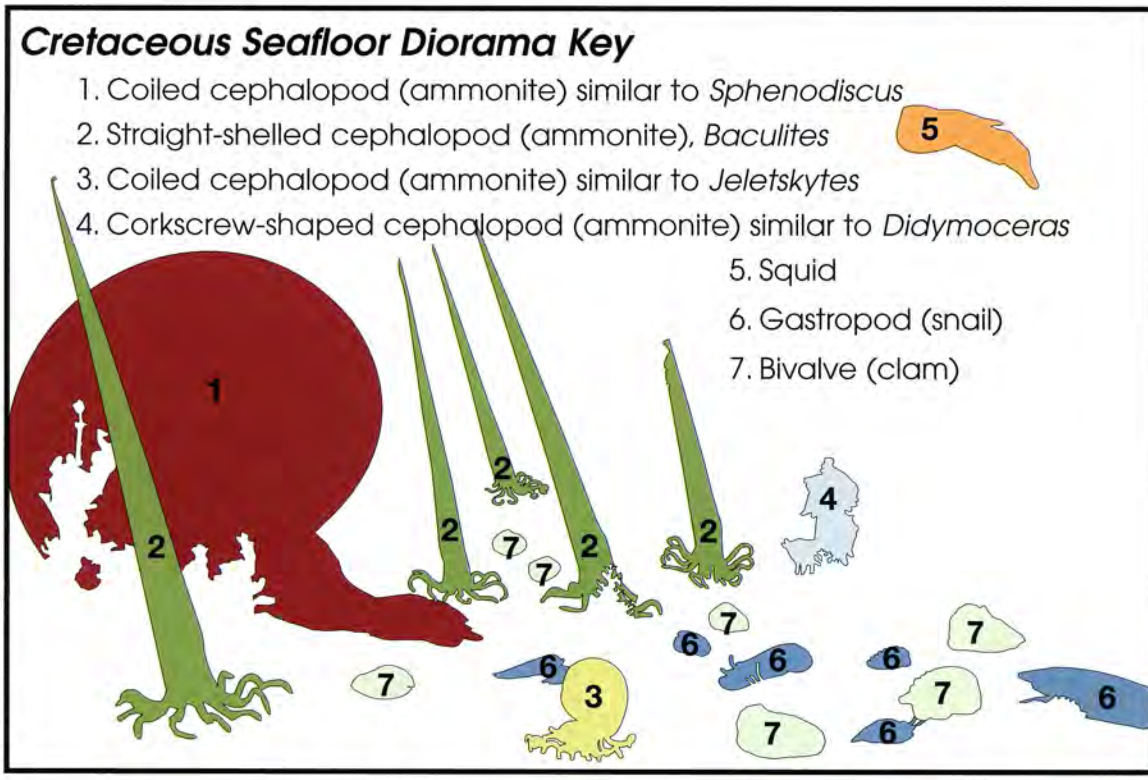


Photo by John Hoganson

This diorama illustrates a Cretaceous seafloor community. North Dakota was covered by warm, shallow oceans during the Cretaceous from about eighty-five to sixty-five million years ago. Fossils of animals similar to many of those shown here have been found and are illustrated on the following pages. Right: Photograph of Niobrara and Pierre Formation outcrops near Walhalla in Cavalier County. Left: Map indicating where outcrops of the Pierre and Fox Hills Formations are found.



Key by Robin Pursley

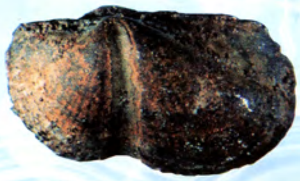
During the Cretaceous Period, from about eighty-five million to sixty-five million years ago, North Dakota was either completely or partially covered by shallow, subtropical to warm-temperate oceans similar to those that had covered the state during Paleozoic times. These oceans occupied what is called the Western Interior Seaway, so called because at times they were extensive enough to connect the Arctic Ocean with the Gulf of Mexico, splitting the North American continent in two. In North Dakota these Cretaceous seas were probably never more than about five hundred feet (150 m) deep. Fine-grained sediments, mostly silt and clay, deposited on the floor of those oceans have become rock and now make up the Carlile, Niobrara, and Pierre Formations. Near the end of the Cretaceous, shallow marine and shoreline habitats existed in central North Dakota, as indicated by sandstones and siltstones of the Fox Hills Formation. These Cretaceous marine rocks are the oldest rocks exposed in the state and contain fossils of the animals and plants that inhabited these ancient oceans.

We know these oceans were shallow and warm primarily because of the fossilized remains of the animals that lived in them. One fossil site that illustrates what a Cretaceous underwater animal community was like is the seventy-five-million-year-old Pierre Formation site in Griggs County near Cooperstown. Fossils of corals, gastropods (*Trachytriton*), bivalves (*Nemodon, Inoceramus*), cephalopods (*Didymoceras, Solenoceras,* and *Baculites*), shrimp (*Callianassa*), crabs, echinoderms (starfish and sea urchins), coral-like bryozoans, and clam-like brachiopods (*Lingula*) are found weathering out of the rocks there. The most spectacular fossils discovered at the Cooperstown site, however, are those of the large vertebrate animals: mosasaurs, sea turtles, sharks, and seabirds.[8]

A nearly complete twenty-three-foot-long (9 m) skeleton of the mosasaur *Plioplatecarpus* was collected from this site by the North Dakota Geological Survey and is now on display at the North Dakota Heritage Center. Mosasaurs were huge marine lizards, some forty feet (12 m) or more in length, that inhabited the world's oceans during the Cretaceous. The name *mosasaur* means "Meuse Reptile" and refers to the initial discovery of fossils of these animals in the 1770s along the Meuse River near the town of Maastricht in the Netherlands. Mosasaurs are related to monitor lizards such as the Komodo dragon that lives in Indonesia today. Unlike those of their terrestrial lizard relatives, mosasaurs' limbs were modified to form paddles or flippers. They swam by moving the back parts of their bodies and flattened tails from side to side. Their paddles were used primarily for steering rather than for propulsion. Mosasaurs were active predators and among the main carnivores in the Cretaceous oceans. They had a good sense of sight and a poor sense of smell. They probably preyed on other mosasaurs, fish, turtles, and invertebrates such as cephalopods. Although mosasaurs were not dinosaurs, they lived at the same time as dinosaurs and also became extinct when they did—about sixty-five million years ago.

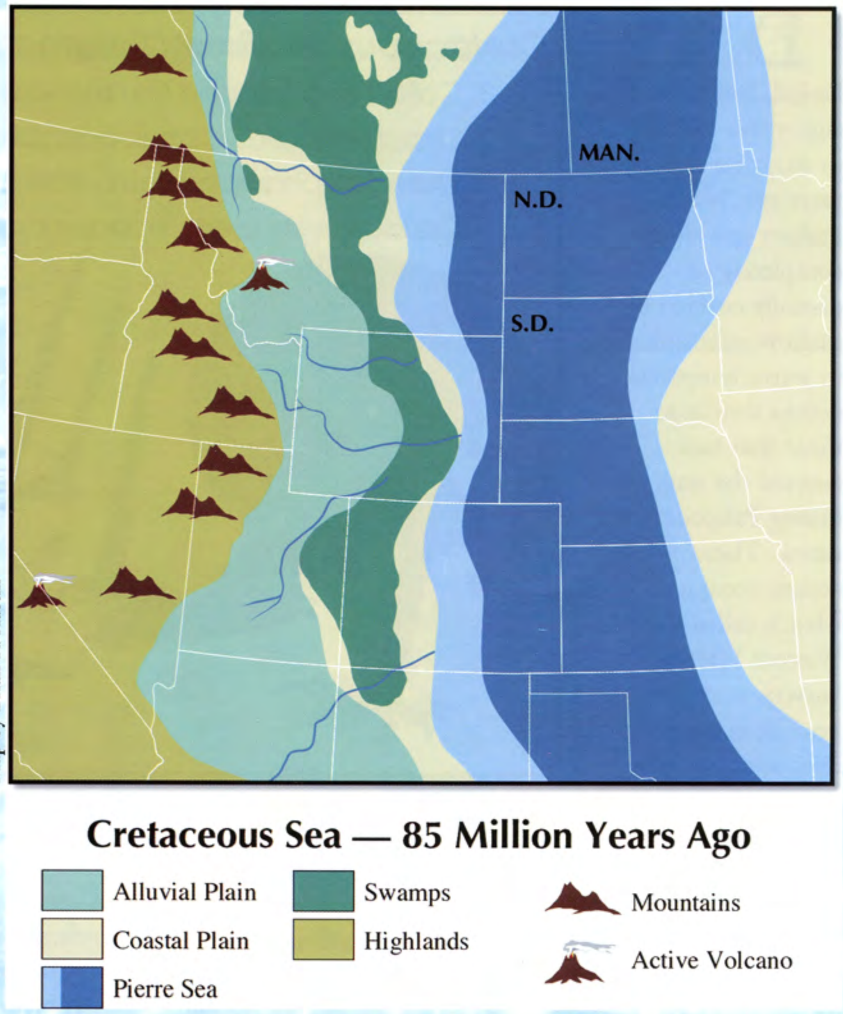
Teeth of several species of sharks, including the "tiger shark" *Squalicorax* and the "dogfish shark" *Squalus*, have also been found in the Pierre Formation at the Cooperstown site. Sharks, rays, and ratfish are in the group of fish (Chondrichthyes) whose skeletons consist mostly of cartilage rather than bone. We generally only find teeth of these fish because their cartilaginous skeletons seldom fossilize before decomposing. These ancient tiger sharks were predators high on the food chain that probably competed with mosasaurs for prey. Dogfish sharks, which still exist, are small sharks that grow to lengths of about three feet (1 m).

Brachiopod
Lingula
Length 4 mm
ND 95-12



Bivalve
Nemodon
Width 3 mm
ND 00-11

Map by Brian R. Austin

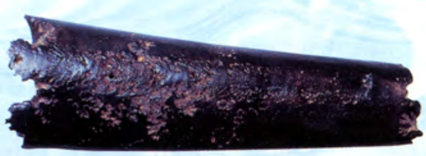


Map of the Western Interior Seaway, which was occupied by oceans during the Cretaceous from about eighty-five to sixty-five million years ago.

All fossils on this page are from the Pierre Formation and, unless otherwise indicated, were found near Cooperstown, Griggs County.

Cephalopod
Solenoceras mortoni
Length 22 mm
ND 00-11.3

Coral
Height 9 mm
ND 00-11.10



Cephalopod
Baculites gregoryensis
Length 56 mm
ND 00-11.5

Bivalve
Inoceramus
Bowman County
Width 68 mm
UND 1332A

Gastropod
Trachytriton
Height 20 mm
ND 00-11.9

Cephalopod
Didymoceras
Height 27 mm
ND 00-11

Shrimp claw
Callianassa
Width 20 mm
ND 00-11.2

Left: This skeleton is from one of the mosasaurs called *Plioplatecarpus* that inhabited the Pierre Sea about seventy-five million years ago. It was discovered in 1995 by Mike Hanson and Dennis Halvorson on Orville and Beverly Tranby's farm in the Sheyenne River valley near Cooperstown, Griggs County, North Dakota. A study of the nearly complete skull and other parts of the skeleton indicate that this is a new species of *Plioplatecarpus* that has not been found anywhere else in the world. The skeleton is twenty-three feet (7 m) long. ND 97-115.1

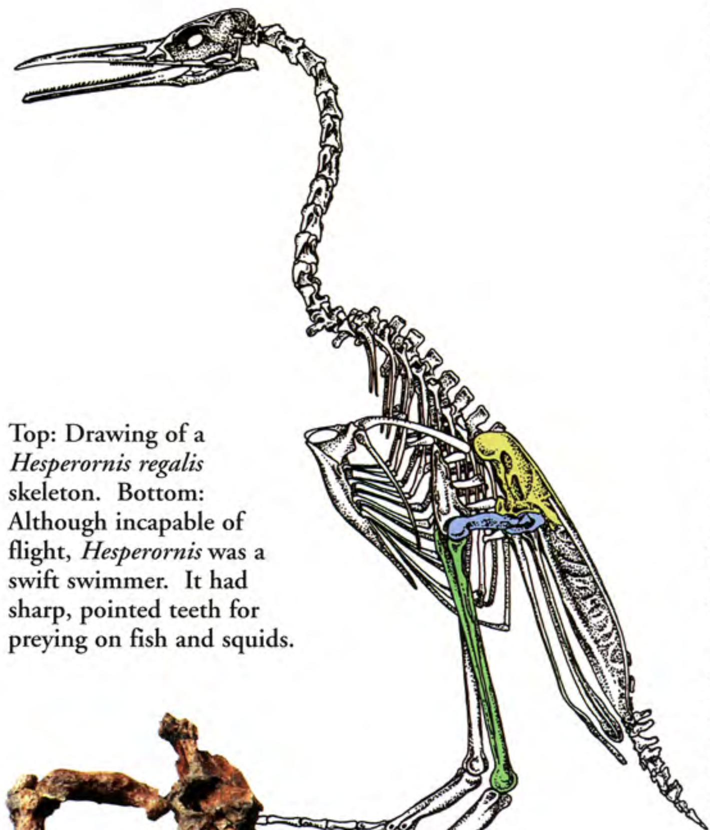
Beverly and Orville Tranby and Bev's sisters, Gloria Thompson, Jacqueline Evenson, and Susan Wilhelm, donated this fossil to the North Dakota State Fossil Collection for exhibit and study at the North Dakota Heritage Center.

This painting depicts an animal community that lived in the shallow-water, subtropical Pierre Sea that covered North Dakota about seventy-five million years ago. The scene is based on fossils found in the Pierre Formation at a site near Cooperstown, Griggs County. The large, predatory mosasaur *Plioplatecarpus* is attacking the diving seabird *Hesperornis*. *Hesperornis* has just captured a salmon-like fish, *Enchodus*. In the background the carcass of a decaying *Plioplatecarpus* is being scavenged by a frenzied group of dogfish sharks, *Squalus*. The mosasaur on exhibit at the Heritage Center was found in this position, with gnaw marks on some of its bones from feeding dogfish sharks. In the painting, the large sand-tiger shark *Carcharias* cruises near the sea floor. Shells of an ammonite, *Sphenodiscus*, with a snail crawling on it, and of the large clam *Inoceramus*, encrusted by oysters, litter the bottom.

Painting by David Miller, North Dakota Heritage Center

They usually live in schools and eat bony fish, other sharks, various invertebrate animals, and even marine mammals. We know that *Squalus* was also a scavenger of mosasaur carcasses during the Cretaceous because we have found gnaw marks on bones of our *Plioplatecarpus* and other mosasaur skeletons that are identifiable as having been produced by *Squalus* teeth. It is likely that sharks at times would prey on mosasaurs, and at other times mosasaurs would prey on sharks.

Prey of both sharks and mosasaurs was *Hesperornis*, a large diving seabird that grew to about five feet (1.5 m) tall. Although incapable of flight, it was a swift swimmer that could propel itself through the shallow coastal waters of the Pierre Sea with its powerful hind legs and grebe-like webbed feet. Its jaws were equipped with sharp, pointed teeth adapted for preying on fish and squids. Other sites in North Dakota, particularly the Pembina Gorge and McCanna sites, have also produced fossils of some interesting "sea monsters" that inhabited the Pierre Sea. The remains of another species of mosasaur, at least twice as big as our *Plioplatecarpus* skeleton, were recently found near McCanna. Fossils from the huge tarpon-like fish *Xiphactinus* have been collected from the Pembina Gorge site. *Xiphactinus*, which grew up to eighteen feet (5.5 m) long, was among the largest bony fishes

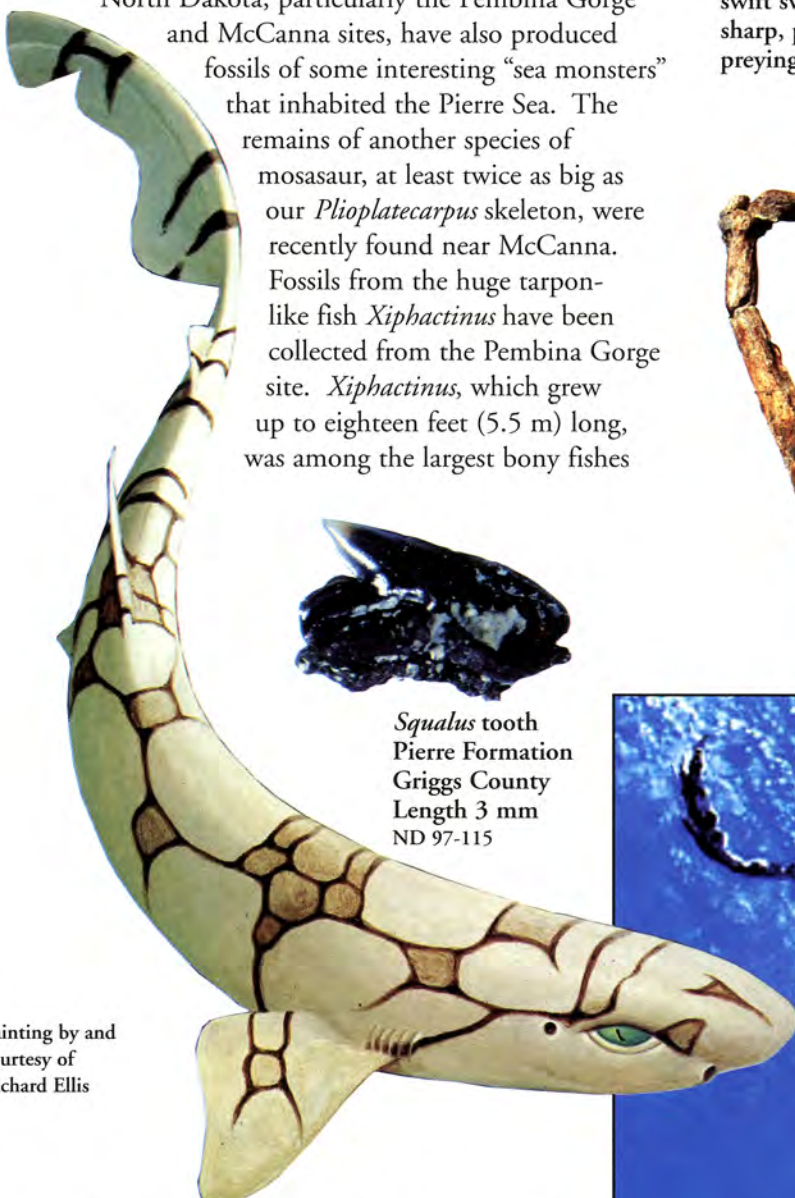


O.C. Marsh, *Odontornithes: A Monograph on the Extinct Toothed Birds of North America* (1880)

Top: Drawing of a *Hesperornis regalis* skeleton. Bottom: Although incapable of flight, *Hesperornis* was a swift swimmer. It had sharp, pointed teeth for preying on fish and squids.

Pelvis, femur, and tibia
Hesperornis regalis
Pierre Formation
Cavalier County
Length 280 mm
ND 06-12.2

***Squalus* tooth**
Pierre Formation
Griggs County
Length 3 mm
ND 97-115



Painting by and courtesy of Richard Ellis

The *Squalus* tooth shown above is almost identical to that of the modern dogfish shark illustrated here.

Painting by and courtesy of Dan Varner

to inhabit the Pierre Sea. Its large size, long body, powerful tail, and bulldog-like jaws suggest it was an efficient predator. *Xiphactinus* had large, ghoulish fangs at the front of its mouth, which it probably used to strike prey during initial attack.

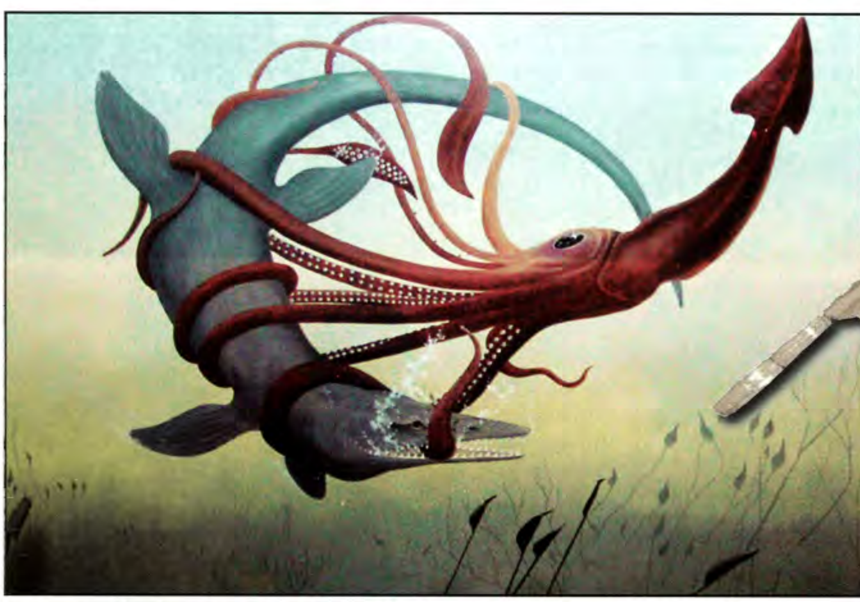
The remains of another huge animal, a giant squid called *Tusoteuthis longa,* have also been found at Pembina Gorge. Squids, although they are invertebrates, have a rigid support structure in their bodies called a *gladius* or *pen.* The pen is in many ways similar to a backbone but is made of shell-like material, not bone. These pens are rarely found as fossils. One was discovered at the Pembina Gorge site, however, and it is six feet (1.8 m) long—indicating that the squid from which it came was a giant, perhaps fifteen feet (4.5 m) long!

By about sixty-eight million years ago the Pierre Sea had receded from western North Dakota, and the huge Hell Creek Delta—similar to the Mississippi Delta today—had begun to form. The eastern edge of this delta was near Bismarck. The shoreline of the Fox Hill Sea (the name geologists give to the less-extensive ocean that replaced the Pierre Sea) was located in south-central North Dakota. Associated with this shoreline were estuary and lagoon habitats that formed adjacent to the delta. The sands, silts, and muds deposited in these shallow marine areas are called the Fox Hills Formation. We know a great deal about invertebrate life in the shallow marine Fox Hills waters because of the abundant and beautifully preserved fossils found in this formation.[9] Among them are bivalves (*Corbicula, Tancredia, Crassatellina, Panopea*), gastropods (*Euspira*), cephalopods (the ammonites *Sphenodiscus lenticularis* and *Jeletzkytes nebrascensis*), sea urchins, lobsters, horseshoe crabs (*Casterolimulus kletti*), shrimp (*Callianassa*) and their burrows (*Ophiomorpha*), and many others. At times these fossils provide information about the behavior and interaction between animals. Breakage of many snail shells, for example, indicates predation by crabs and other animals.[10]

Remains of vertebrate animals that inhabited the Fox Hills Sea are less abundant but include sharks (*Carcharias* and *Squalicorax*), ratfish (*Ischyodus rayhassi*), rays (*Myledaphus bipartitus*), and several species of bony fish (e.g., *Vorhisia vulpes*).[11] Sea turtles and mosasaurs also resided in the shallow marine and estuarine habitats.[12] Mosasaurs and sharks were the main predators in these waters, with ratfish and rays feeding primarily on the invertebrates. As would be expected, remains of animals that lived on the delta—salamanders (*Opisthotriton kayi, Lisserpeton bairdi*), turtles, crocodiles (*Borealosuchus*), crocodile-like champsosaurs, birds, and dinosaurs (*Tyrannosaurus*)—would occasionally be washed into the marine waters and are now part of the Fox Hills Formation fossil record.[13]

Painting by and courtesy of Dan Varner

The tarpon-like *Xiphactinus,* which grew up to eighteen feet (5.5 m) long, was among the largest fish to inhabit the Pierre Sea and an efficient predator.



Painting courtesy of the Canadian Fossil Discovery Centre

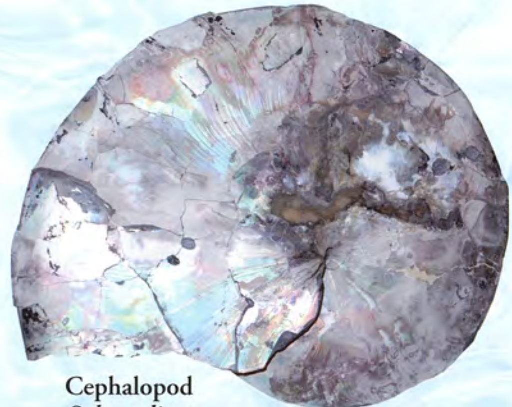
Pen
Tusoteuthis longa
Pembina County
Length 1.8 m
ND 00-60.1

A *Tusoteuthis longa* squid locked in battle with a mosasaur. Right, pen of a *Tusoteuthis,* found near Walhalla at the Pembina Gorge site. This pen would have been part of the spear-like tail of the squid, and indicates an animal perhaps fifteen feet (4.5 m) long.

Map by Robin Pursley

Map of the Hell Creek Delta as it formed in western North Dakota while the Pierre Sea receded. The less extensive ocean that followed the Pierre Sea is known as the Fox Hill Sea.

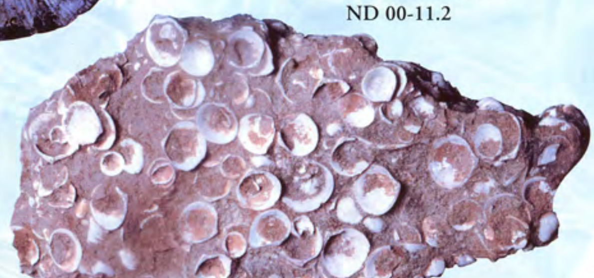
These shells, remains of invertebrate animals, are examples of the beautifully preserved fossils found in the Fox Hills Formation. Most of the animals represented by these fossils lived near the Fox Hills Sea shoreline; these species indicate that the sea was warm. The shell of *Sphenodiscus lenticularis* (a type of ammonite) is perforated by several small punctures, probably caused by predation, possibly by a mosasaur.



Cephalopod
Sphenodiscus lenticularis
Emmons County
Width 365 mm
ND 99-118.1

Gastropod
Euspira
Logan County
Length 23 mm
ND 99-6

Cephalopod
Jeletzkytes nebrascensis
Emmons County
Width 118 mm
ND 7.2



Bivalves
Corbicula
Morton County
Width 281 mm
ND 00-11.2

Bivalve
Tancredia
Logan County
Width 42 mm
ND 99-6

Bivalve
Panopea
Sioux County
Width 105 mm
ND 00-6.2

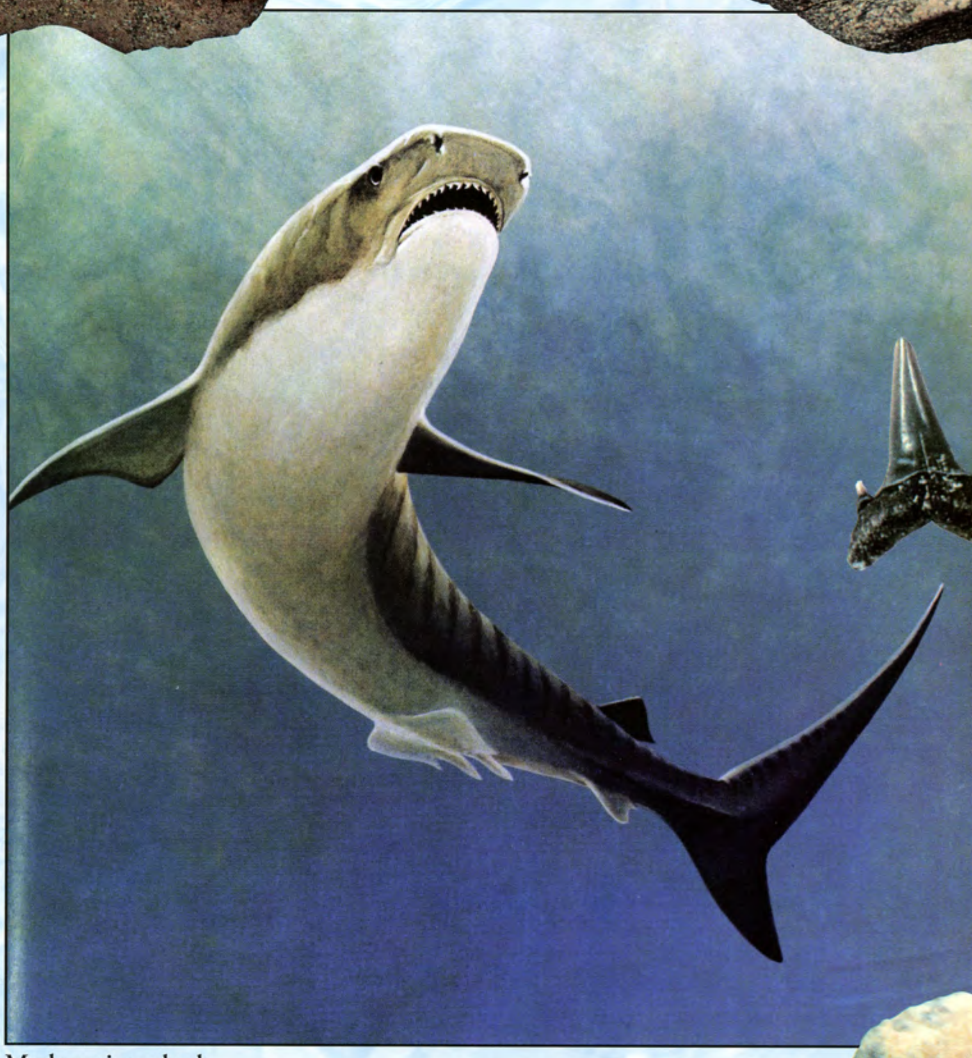
Bivalve
Crassatellina hollandi
Logan County
Width 159 mm
ND 95-13.1

Sea Urchin
Emmons County
Width 42 mm
ND 21.3

Fossils of vertebrate animals from the Fox Hill Formation consist mostly of isolated fish teeth and dental plates. Fish ear stones—structures in the inner ear of bony fish like *Vorhisia vulpes*, a catfish—are unusual fossils also found in the Fox Hills Formation. These fossils indicate the kinds of predators that lived in the Fox Hills Sea.

Shark tooth
Squalicorax pristodontis
Bowman County
Width 22 mm
SLU 1832

Ratfish dental plate
Ischyodus rayhaasi
Logan County
Width 65 mm
ND 99-6.1



Painting by and courtesy of Richard Ellis

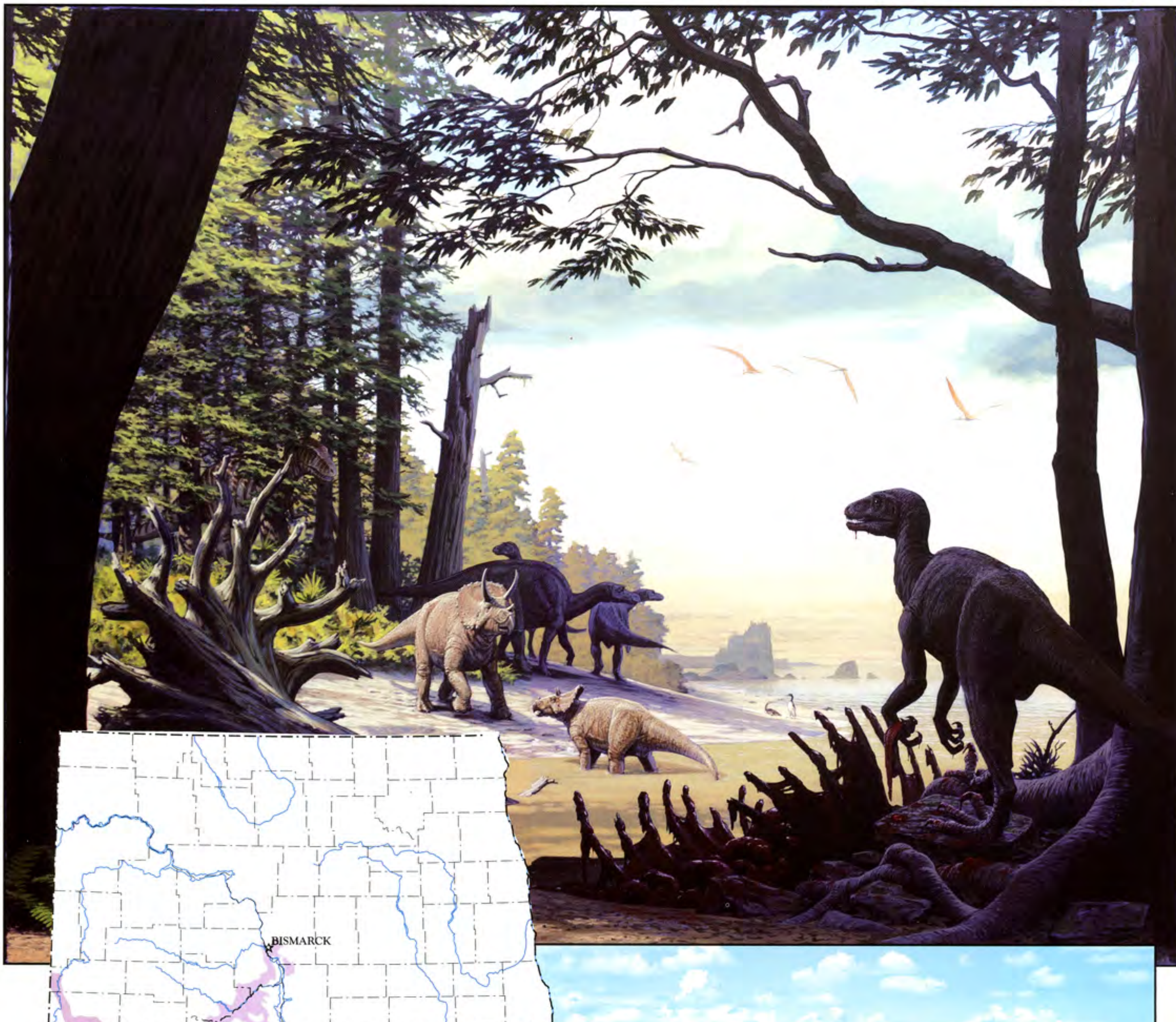
Modern tiger shark

Shark teeth
Carcharias
Griggs County
Height 7 mm
ND 95-40

Catfish ear stone
Vorhisia vulpes
Logan County
Width 4 mm
ND 95-13.35

Ray tooth
Myledaphus bipartitus
Morton County
Height 7 mm
UND RMF134-80-3

When Dinosaurs Ruled the Hell Creek Delta

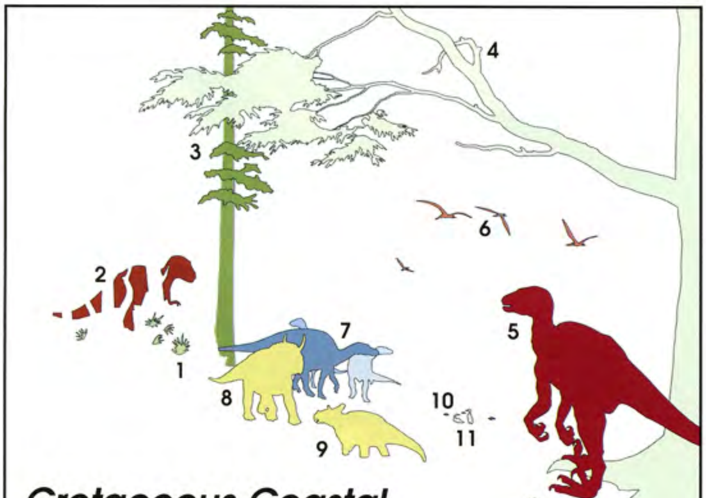


North Dakota Heritage Center

Map by Brian R. Austin

Photo by John Hoganson

Mural depicting what the coastal forest on the Hell Creek Delta bordering the Western Interior Seaway may have looked like in North Dakota about sixty-five million years ago. Sediments deposited in the delta are known as the Hell Creek Formation. Right: Outcrop in Sioux County showing the Fox Hills Formation overlain by the Hell Creek Formation. Above: This map shows areas in North Dakota where the Hell Creek Formation is exposed.



Cretaceous Coastal Forest Mural Key

1. *Sabalites*	7. *Edmontosaurus*
2. *Tyrannosaurus rex*	8. *Triceratops* - adult
3. *Metasequoia*	9. *Triceratops* - juvenile
4. *Liriodendrites*	10. Sea turtles
5. Dromaeosaur	11. *Hesperornis*
6. *Pteranodon*	

Key by Brian R. Austin

These plant fossils indicate the Hell Creek coastal forest contained a wide variety of trees and other plants, including conifers, palms, cycads, and magnolias.

Conifer cone
Metasequoia
Hell Creek Formation
Morton County
Height 52 mm
ND 93-6.3

Cycad leaf
Nilssoniocladus
Fox Hills Formation
Emmons County
Length 147 mm
ND 02-17.13

Magnolia leaf
Liriodendrites
Fox Hill Formation
Emmons County
Length 120 mm
ND 03-1.75

Palm tree leaf
Sabalites
Hell Creek Formation
Slope County
Width 512 mm
ND 06-8.1

The Hell Creek Delta was the eastern edge of a well-drained lowland corridor that existed between the rising Rocky Mountains to the west and the Western Interior Seaway (Fox Hills Sea) to the east during the Late Cretaceous. As the Rocky Mountains rose through tectonic pressures generated deep within the Earth, sediments eroded from them were carried eastward by rivers and streams and formed a fan-shaped delta, much like today's Mississippi River delta in Louisiana, once they reached the Fox Hills Sea. These sediments,

Detail from mural of *Triceratops* in the Hell Creek Delta coastal forest. Above: *Triceratops horridus* skull on display in the North Dakota Industrial Commission office building in Bismarck. The skull was collected by the North Dakota Geological Survey in Slope County from USDA Forest Service-Dakota Prairie Grasslands-administered land. It is five feet (1.5 m) long.
ND 92-19.1

now turned into sandstone, siltstone, and mudstone, are called the Hell Creek Formation (see the map of the Hell Creek Delta on page 14).

Many areas of this delta plain were forested. The Hell Creek Delta woodlands contained hundreds of species of plants dominated by angiosperms, which were mostly small- to medium-sized flowering trees.[14] In some ways the forest resembled living mixed deciduous and evergreen broad-leafed forests; it differed, however, in that most of the plants making up the ancient forest are now extinct. A coastal marsh forest containing cycads, palms, ferns, conifers, and many other exotic plants existed along the Fox Hills Sea shoreline in central North Dakota.[15]

North Dakota's climate during the Late Cretaceous was warm-temperate to subtropical, probably similar to that of south Florida today. The woodlands, ponds, and swamps that existed here at that time provided abundant habitats for many types of animals, including several species of dinosaurs.

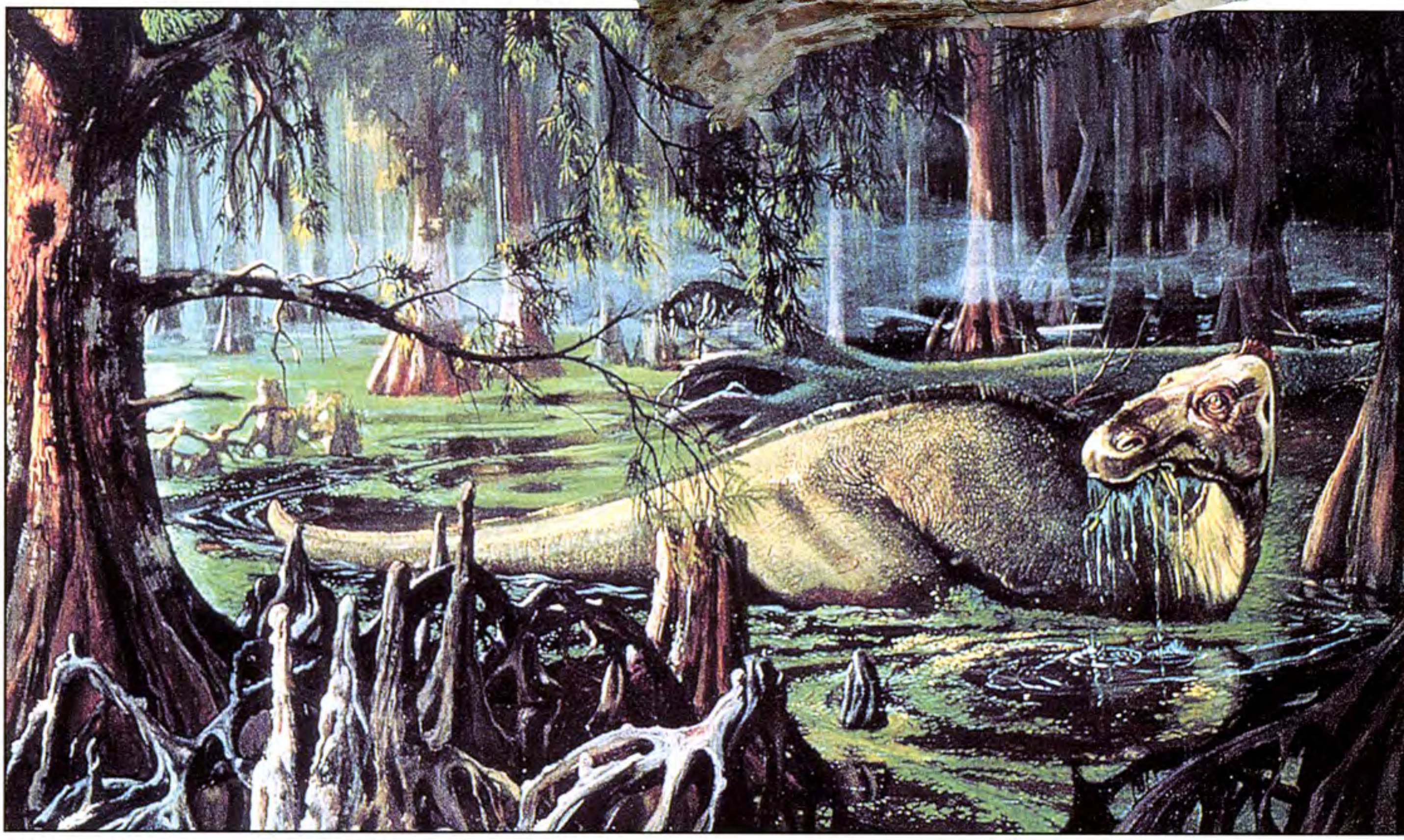
The Hell Creek Formation is the only rock formation in North Dakota that contains abundant dinosaur remains. Fossils of fourteen species have been discovered here.[16]

The Hell Creek dinosaur community was dominated by large herbivores. *Triceratops, Torosaurus, Edmontosaurus, Pachycephalosaurus, Stygimoloch,* and *Thescelosaurus* were among the dinosaurs that fed on the lush delta woodland vegetation.

One of the most common, and consequently one of the best known of the large Hell Creek herbivores is *Triceratops*. *Triceratops* ("three-horned face") was among the largest and heaviest of the plant-eating, horned (ceratopsid) dinosaurs. This creature grew to lengths of about twenty-five feet (8 m) and could weigh as much as eight and a half tons. It was at least three times the size of the largest living rhinoceros.[17] Even though its front legs were short, they were powerfully built to support the weight of its extremely heavy head. *Triceratops* skulls, often at least six feet (1.8 m) long in adult specimens, are distinctively equipped with two long brow horns, one short nose horn (hence its name), and a large, solid bone frill that covered its neck. The function of the frill and horns has been debated for many years. Damage to many *Triceratops* skulls suggests that these animals probably sparred with one another by locking horns and shoving and twisting, possibly to win mates or establish territory.[18] It is

Right: Lower jaw of *Edmontosaurus*, a duck-billed dinosaur. The back of the jaw is to the right. Note the dense batteries of small teeth. Found by Tyler Lyson, Marmarth, in the Hell Creek Formation in Slope County, width 487 mm.
ND 06-6.1

Below: Painting of *Edmontosaurus* in a coastal swamp.

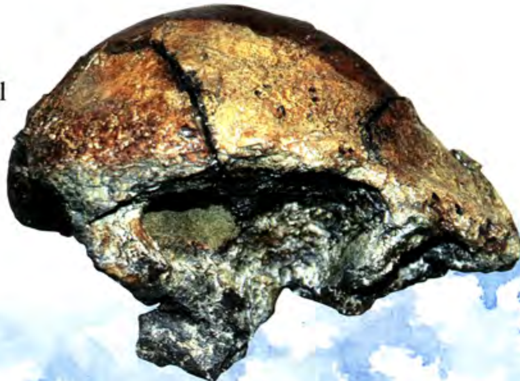


Painting by Eleanor Kish, reproduced with permission of the Canadian Museum of Nature, Ottawa

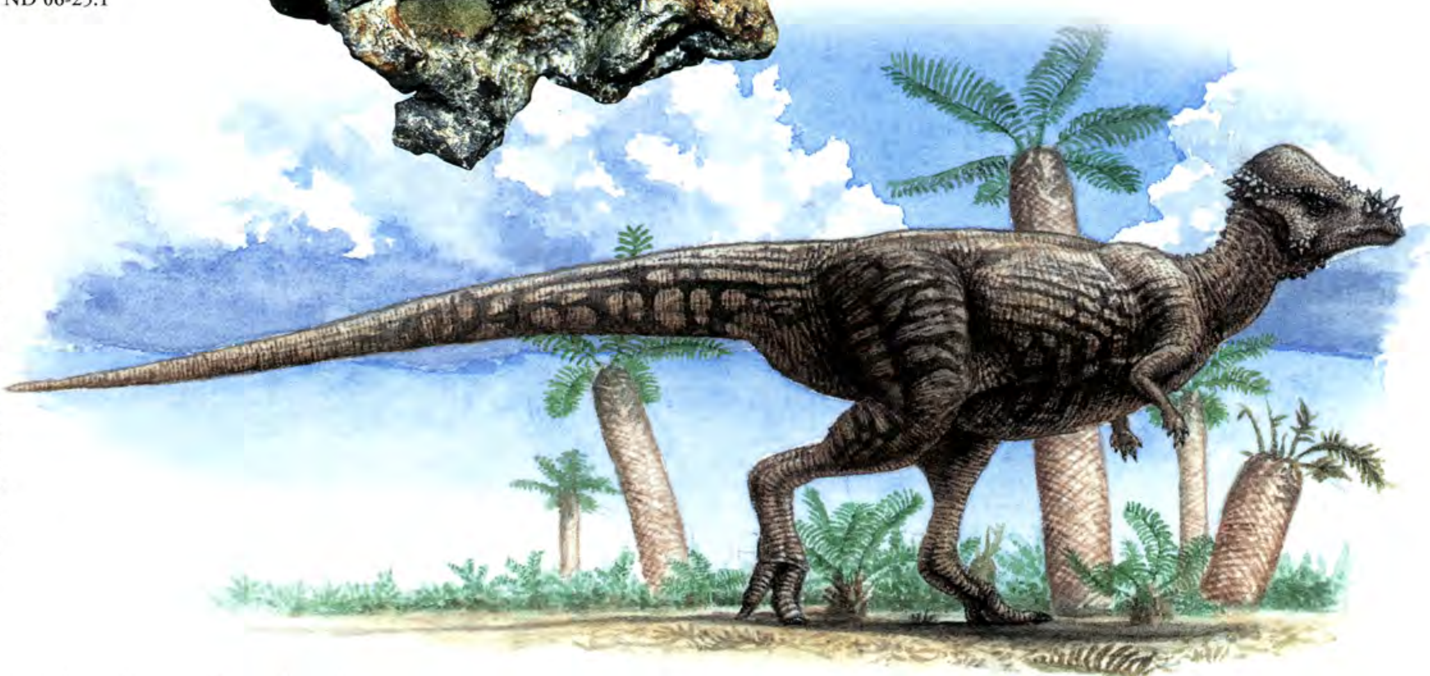
easy to imagine that *Triceratops* may have charged predators such as its contemporary, *Tyrannosaurus rex*, much as an enraged rhinoceros does today. The horns and frills may also have been used to help regulate body temperature. Its powerful jaws ended in a parrot-like beak and contained batteries of small teeth adapted for shearing fibrous plants. *Triceratops* was one of the last dinosaur species to ever live on Earth.

The duck-billed (hadrosaurid) dinosaur *Edmontosaurus* was another of the common herbivores that resided in North Dakota at the end of the Cretaceous. A hadrosaur face was elongated into a broad, flattened snout with a toothless beak. This flattened snout looked rather like the bill of a modern duck, hence the popular name "duck-billed dinosaur." *Edmontosaurus* used its beak for foraging, possibly to strip bark and leaves from trees.[19] There were several species of hadrosaurs, and their skeletons are remarkably similar, so generally the skull must be found to identify the exact species of the animal. *Edmontosaurus* was one of the

***Edmontosaurus* skin impression. Found by Tyler Lyson, Marmarth, in the Hell Creek Formation in Slope County, width 180 mm.**



Pachycephalosaurus skull
Hell Creek Formation
Slope County
Width 137 mm.
ND 06-25.1



Courtesy of Natural History Museum, London

Artist's rendering of a *Pachycephalosaurus* in an environment similar to that of the Hell Creek Delta. The trees in the background are cycads. A fossil cycad leaf is shown on page 17.

largest hadrosaurids, growing to forty feet (12 m) long and weighing about four tons. It is also one of the best-known dinosaurs because many *Edmontosaurus* skeletons have been found and studied. It had large pillar-like legs, powerful ankles, and bony tendons along its backbone that helped support the animal as it walked. Each foot possessed three broad, widely spaced toes ending in hoof-like nails. Unlike many duck-billed dinosaurs, *Edmontosaurus* was "flat-headed" and did not have a skull with a crest. It did have strong lower jaws that contained batteries of hundreds of small teeth, which formed grinding surfaces for eating coarse vegetation. These teeth acted like a rasping file and could pulverize tough plant food such as conifer needles, twigs, and cones. There were no teeth in the front of the mouth. Worn teeth were continually replaced by new ones throughout the life of the animal. Rare mummified *Edmontosaurus* skeletons preserve skin impressions, which indicate that it had a thin, leathery hide studded with horny bumps, or tubercles. Bite marks on *Edmontosaurus* bones indicate that *Tyrannosaurus rex* preyed on, or at least scavenged, this dinosaur.[20] Its only real defense against predators would have been to run away from danger. Many hadrosaurs lived in large herds, and some may have cared for their young at nesting sites.[21] It has been speculated that *Edmontosaurus* may have traveled thousands of miles annually, perhaps along migration routes, because fossils of this species have been found at the North Slope of Alaska.[22]

Fossils of the two-legged, herbivorous "thick-headed" dinosaurs *Pachycephalosaurus* and *Stygimoloch* are uncommon in the Hell Creek Formation, and only a few specimens have been found in North Dakota.[23] Both of these dinosaurs are called pachycephalosaurs because of their thickened skull roofs. In fact, the skull cap is often the only part of the animal that is preserved. The function of the thick dome skulls of pachycephalosaurs has been a matter of debate. Some paleontologists believe they were for sexual display; others think they were used for combat with rivals, as in head-to-head butting or flank butting.[24] The skull of *Pachycephalosaurus* was studded with bony knobs, while the skull of *Stygimoloch* was decorated with long spikes. These bipedal dinosaurs were not large—*Pachycephalosaurus* was about fifteen feet (4.5 m) long, and *Stygimoloch* about seven (2 m). They were browsers and ate leaves, stems, fruits, and possibly insects.[25]

Another of the small plant-eating dinosaurs that inhabited the Hell Creek Delta in North Dakota was the hypsilophodont *Thescelosaurus* ("marvelous lizard"). Hypsilophodont dinosaurs were quite small and fast bipedal runners. *Thescelosaurus* was about twelve feet (3.5 m) long and three feet (1 m) tall at the hips, with a long tail, short legs, and a small head. An extremely rare articulated skeleton of *Thescelosaurus* recently found near Marmarth indicates that it had dermal armor (bony plates imbedded in the skin).[26] It was a forager, feeding on ground cover and shrubby vegetation.[27]

As in ecosystems today, herbivores far outnumbered carnivores in the Hell Creek dinosaur community. Fossils of meat-eating dinosaurs, the theropods, are consequently much less common than those of plant eaters. Nevertheless, several species of carnivorous dinosaurs did inhabit North Dakota during the Late Cretaceous, including arguably the most spectacular of them all, *Tyrannosaurus rex*. *T. rex* was one of the largest terrestrial carnivores of all time. Adults grew to lengths of forty feet (12 m), measured from the tip of the nose to the end of the tail, and weighed about six to eight tons. They stood up to twenty feet (6 m) tall on their hind legs. Heads of the adults were huge, about five feet (1.5 m) long, and possessed approximately fifty large, dagger-like teeth, some as large as bananas.[28] These blade-like serrated teeth could puncture bone and carve through flesh. The long, heavy tails of *T. rex* were held off the ground to counterbalance their heads. Bipedal, their legs were long and powerfully built, with three forward-pointing toes on each broad foot. Each toe ended in a sharply curved talon. Their arms were very short, with two clawed fingers on each hand. A *T. rex* could tear off as much as five hundred pounds (225 kg) of flesh at one time with its powerful jaws.[29] It had a keen sense of smell and could travel at high speeds for short distances.

Since fossils of *Tyrannosaurus rex* were first described by H.F. Osborn in 1905, the "Tyrant Lizard King" has been viewed as the most fearsome predatory animal of all time by the public and paleontologists alike.[30] Conceptualizations of *T. rex* as primitive and savage have fueled many school children's nightmarish dreams and, for some, have even provided the impetus to pursue careers in paleontology.

> *A huge vegetable-feeding dinosaur* Trachodon *[duck-billed dinosaur] waddles along the shore. . . . Suddenly it hears a sound. Swinging about, it sees the gigantic figure of* Tyrannosaurus *dimly outlined among the trees of the forest's edge. . . . Wild with fear, the* Trachodon *hurries toward the water. But its fat, hulking body can only move slowly. In two leaps, the King of Tyrants lands on its back. The giant's head seems to split apart as the great mouth opens and clamps shut on the Duckbill's neck. The dagger-like teeth crunch through bones and flesh like shears cutting paper. There is a frantic thrashing for a time as the colossal beasts roll in the slippery muck. Then the* Trachodon *lies still. Its head hangs loosely, almost severed from the neck by six-inch teeth. . . . For a few moments the Tyrant King gazes into the dark reaches of the jungle. . . . Then it settles to the feast. Huge chunks of warm flesh, torn from the Duckbill's body, slide down the cave-like throat.*[31]
>
> *R.C. Andrews,* All about Dinosaurs, *1954*

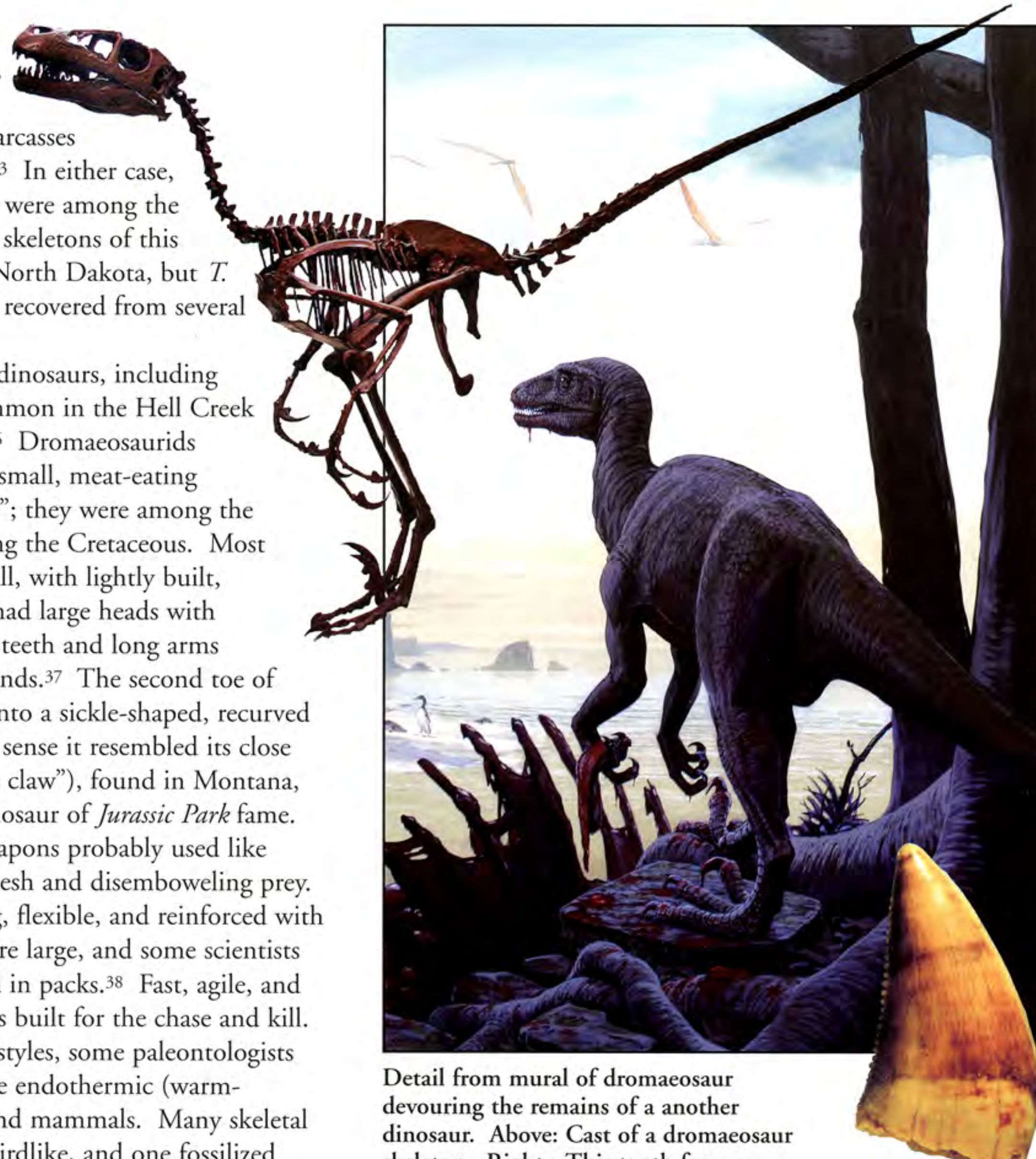
In recent years, however, a debate has developed over whether *T. rex* was an active hunter or a mere scavenger.[32] P.J. Currie's active-hunter argument is based on its long and massive teeth, long and strong legs for running down prey, and stereoscopic vision (indicated by the placement of the eye sockets). J.R. Horner and D. Lessem's assertion that *T. rex* was a scavenger is based on its relatively small eyes and small arms—too small, they believe, to have easily held onto

Painting by and courtesy of John Sibbick

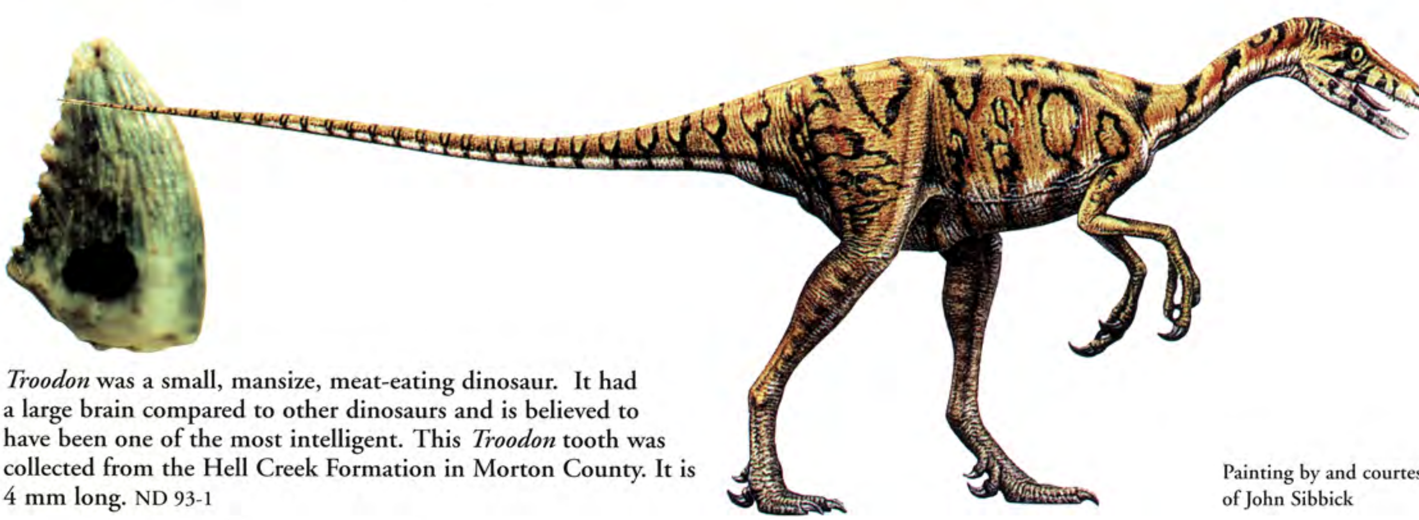
Tyrannosaurus rex in a Late Cretaceous habitat. No complete skeletons of this dinosaur have been found in North Dakota, but _T. rex._ teeth and bones have been recovered. Above: _Tyrannosaurus rex_ tooth, collected in Morton County. _T. rex_ lost teeth throughout its life, growing replacement teeth much like a shark does. Length of the tooth is 64 mm. ND 93-11.1

prey. It is likely that *T. rex* was an opportunistic predator, possibly hunting in family groups, and would scavenge carcasses when they were encountered.[33] In either case, *Edmontosaurus* and *Triceratops* were among the prey of *T. rex*.[34] No complete skeletons of this dinosaur have been found in North Dakota, but *T. rex* teeth and bones have been recovered from several fossil sites in the state.[35]

Teeth of smaller theropod dinosaurs, including dromaeosaurids, are more common in the Hell Creek Formation in North Dakota.[36] Dromaeosaurids ("swift-running lizards") were small, meat-eating dinosaurs often called "raptors"; they were among the most ferocious predators during the Cretaceous. Most were less than six feet (2 m) tall, with lightly built, speedy bipedal bodies. They had large heads with sharp, serrated, meat-shearing teeth and long arms with clawed, three-fingered hands.[37] The second toe of each hind foot was modified into a sickle-shaped, recurved raptorial claw or talon; in this sense it resembled its close relatives *Deinonychus* ("terrible claw"), found in Montana, and *Velociraptor*, the Asian dinosaur of *Jurassic Park* fame. These claws were offensive weapons probably used like daggers for slashing through flesh and disemboweling prey. Dromaeosaurid tails were long, flexible, and reinforced with delicate rods. Their brains were large, and some scientists believe these dinosaurs hunted in packs.[38] Fast, agile, and intelligent, they were predators built for the chase and kill. Because of their aggressive lifestyles, some paleontologists believe that dromaeosaurs were endothermic (warm-blooded), like modern birds and mammals. Many skeletal features of dromaeosaurs are birdlike, and one fossilized dromaeosaur skeleton even shows the presence of feathers.[39] Indeed, most scientists believe that birds evolved from small, feathered theropod dinosaurs related to dromaeosaurids or troodontids.[40]



Detail from mural of dromaeosaur devouring the remains of a another dinosaur. Above: Cast of a dromaeosaur skeleton. Right: This tooth from a dromaeosaur was collected from the Hell Creek Formation in Morton County. It is 7 mm long. ND 93-1.6



Troodon **was a small, mansize, meat-eating dinosaur. It had a large brain compared to other dinosaurs and is believed to have been one of the most intelligent. This** ***Troodon*** **tooth was collected from the Hell Creek Formation in Morton County. It is 4 mm long.** ND 93-1

Painting by and courtesy of John Sibbick

Coprolite
(fossil feces)
Width 24 mm
ND 95-27.24

Freshwater turtle
Eubaena cephalica
Width 29 mm
ND 06-9.1

Bivalve
Width 114 mm
ND 06-9.1

These turtle and bivalve fossils represent some of the freshwater species that lived in the Hell Creek Delta during the Late Cretaceous. The coprolite is rare; whether it is from a dinosaur or another animal has not been determined. These fossils are from the Hell Creek Formation and were found in Mercer County.

Fossils of *Troodon*, another small meat-eating dinosaur related to the dromaeosaurs, have also been found in the Hell Creek Formation in North Dakota. *Troodon* was a man-sized predator. It grew to lengths of about six feet (2 m) but weighed only around fifty pounds.[41] It had a narrow head, long snout, large eyes, serrated teeth, long, slender hind limbs, and raptorial hands. Like dromaeosaurs, *Troodon* also possessed an enlarged sickle-shaped claw on each foot that likely was used for bringing down prey.[42] Its lightly built body and long, slender legs suggest that it was very agile. It may have had excellent sight and hearing because of its large eye sockets and well-developed middle ear. The size of the brain cavity of *Troodon* compared to its body suggests it was one of the more intelligent dinosaurs. It is thought to have preyed on other dinosaurs, hatchlings, and mammals, and possibly also ate dinosaur eggs and insects.

Because of the dominance of dinosaurs, it is easy to overlook the other animals that were part of the Hell Creek Delta community. Freshwater fishes, salamanders, lizards, turtles, crocodiles, champsosaurs (crocodile-like animals), birds, gastropods, bivalves, and other creatures coexisted with the dinosaurs, and fossils of these animals are also found in the Hell Creek Formation. Rodent-sized mammals lived here, too. One final spectacular animal, however, should be mentioned: the huge flying reptile called *Pteranodon*.

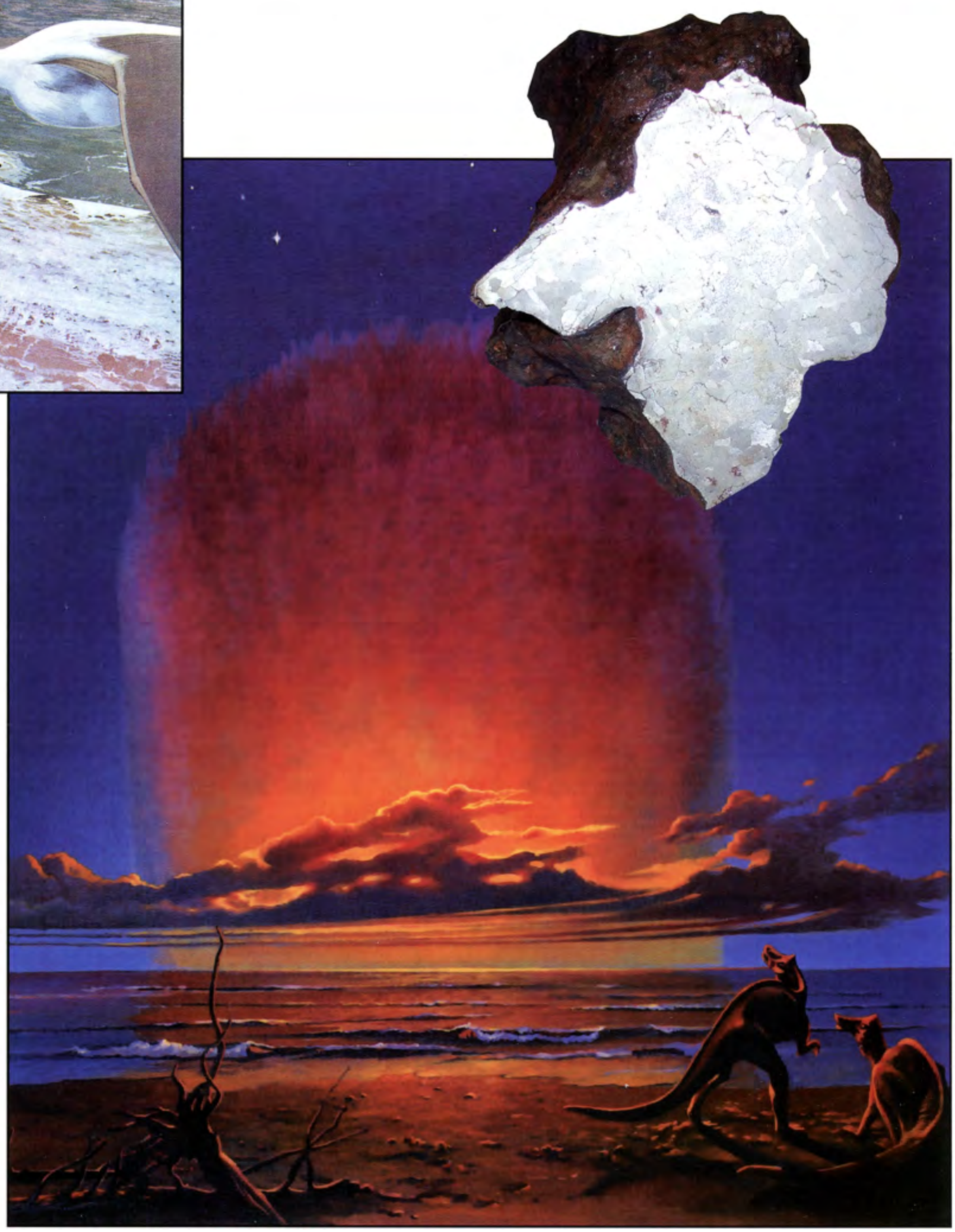
Pteranodon ("toothless flier") was one of the flying reptiles called pterosaurs that lived during the Mesozoic Era.[43] Pterosaurs were not dinosaurs but were their contemporaries and dominated the air as dinosaurs did the land. More than two hundred million years ago during the Triassic Period, pterosaurs were the first vertebrate animals to develop the capability of sustained flight with control over steering and direction. The wing membrane in pterosaurs was stretched over a single long finger termed the "wing finger." The other three fingers terminated in powerful, sharp, curved claws used for climbing rock ledges or trees. Pterosaur bodies were lightly built, and their wing bones, like those of birds, were hollow with extremely thin walls. Their brains were more bird-like than reptile-like. They probably were fairly helpless on land, but they had webbed feet and likely could swim. At least some pterosaurs had hair and fur and were probably warm-blooded. They ranged worldwide and, like dinosaurs and mosasaurs, became extinct at the end of the Cretaceous.

Pteranodon was gigantic. Though its body was quite small, weighing only about thirty-five pounds (15 kg), its wingspan was more than twenty feet (6 m). *Pteranodon* was a powerful flier who also could glide and soar effortlessly on rising air thermals over great distances and for long periods of time. It had a long, thin bone crest at the back of its head that was possibly used for sexual display or functioned as a stabilizer for its long head during flight. The crest could also have served as a counterweight to the animal's long beak. Unlike many pterosaurs, *Pteranodon* did not have teeth. A fish eater, it lived along the coast of the ocean that covered parts of North Dakota at the end of the Cretaceous. Although not closely related to birds, it led a life similar to that of the modern-day albatross, which has a ten-foot (3 m) wingspan and spends most of its life soaring over marine waters. *Pteranodon* lived in North Dakota at the same time as the flightless seabird *Hesperornis*.

Photo by Brian R. Austin

Painting by and courtesy of Donna Braginetz

Top: Cast of a skeleton of the Late Cretaceous flying reptile *Pteranodon.* ND 06-5.1 Above: Several *Pteranodon,* with twenty-foot (6 m) wingspans, soar along the coast of the Western Interior Seaway.



Painting by Eleanor Kish. Reproduced with the permission of the Canadian Museum of Nature, Ottawa

Pteranodon, like the dinosaurs, became extinct about sixty-five million years ago. One possible explanation for the disappearance of these animals is that the Earth was struck by a giant asteroid, as shown in this painting. Such an impact would have dramatically altered global climate, allowing only the most adaptable species to survive. The composition of such an asteroid would have been similar to the iron New Leipzig meteorite that struck North Dakota in 1936. A slice of that meteorite (center), on loan from the National Museum of Natural History, Smithsonian Institution, is on display at the North Dakota Heritage Center.

THE K-T BOUNDARY EXTINCTION

A mass extinction that was one of the greatest biological catastrophes of all time occurred about sixty-five million years ago, marking the end of the Cretaceous Period. This is commonly called the K-T boundary extinction because it occured at the boundary between the Cretaceous and Tertiary Periods. It was global in extent. The last of the dinosaurs and about three-quarters of all plant and animal species worldwide died out at that time.[44] This event marks the end of the Age of Reptiles, the Mesozoic Era, and the beginning of the Age of Mammals, the Cenozoic Era. The cause of the catastrophe is aggressively debated among scientists, but the most intriguing explanation is called the "asteroid impact theory."

According to this explanation, Earth was struck by a huge asteroid or comet about sixty-five million years ago. It has been estimated that the asteroid would have been more than six miles (10 km) in diameter and was traveling at about fifty thousand miles (90,000 km) per hour at impact. It would have been similar in composition to the iron New Leipzig Meteorite that fell in North Dakota in 1936, a slice of which is on display at the North Dakota Heritage Center. The energy released by the impact is calculated to have been equivalent to one hundred million megatons of high explosives, which is more explosive power than was contained in all the world's nuclear weapons during the height of the Cold War and a billion times as much as that released by the atomic bomb dropped on Hiroshima.[45]

A crater one hundred miles (160 km) wide and more than ten miles (16 km) deep has been identified beneath Mexico's Yucatan Peninsula and is believed to be the impact site. The explosion would have vaporized plants and animals within a few hundred miles of the impact site, and the intense heat would have been devastating to life worldwide. A three-hundred-foot-high (90 m) tsunami that washed ten miles (16 k) onto land devastated the Caribbean.[46]

Following the collision, the climate of Earth would have been drastically altered because of dust, other particles, and smoke from wildfires blown into the atmosphere. The resulting "nuclear winter" would have caused global temperatures to drop to near the freezing point, photosynthesis to cease, and land and sea plants to die, including those that lived in North Dakota.[47] Most of the animals and plants that survived the initial explosion and intense heat would have died because of this climate change. Only the most adaptable species would have survived. Because the last of the non-avian dinosaurs disappeared during this event (almost all paleontologists now believe that birds are descendents of dinosaurs and are therefore still with us), almost every schoolchild past the third grade now knows the meaning of extinction. In fact, about 99.9 percent of all species that have ever lived on Earth are now extinct. As Richard Leaky and Roger Lewin have written, "To a paleontologist, death is a fact of life, and extinction is a fact of evolution."[48]

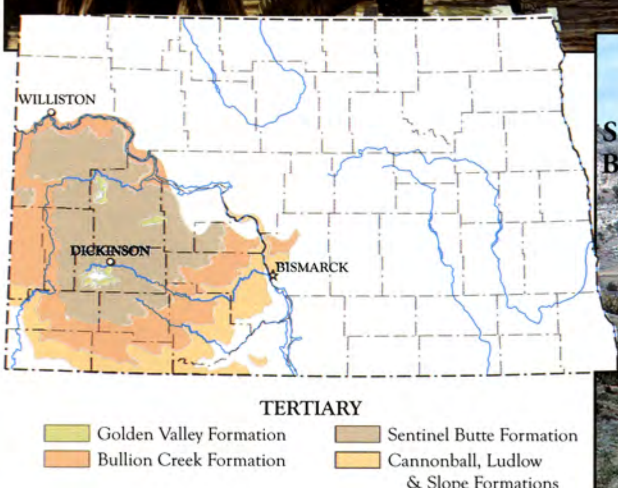
One line of evidence suggesting that Earth was impacted by a huge asteroid sixty-five million years ago is the occurrence of a very thin layer of clay at the Cretaceous-Tertiary (K-T) geological boundary. This clay layer, which can be seen in certain places in North Dakota, is rich in iridium, a platinum-group element rare in Earth's crust but found in high concentrations in celestial bodies such as asteroids or meteors. Many scientists believe that the iridium is left over from the asteroid responsible for the extinction event. There appears to be no doubt that a huge meteor struck Earth at this time.

The "asteroid impact theory" for the K-T boundary extinction is intriguing. It is the kind of doomsday event that producers in Hollywood make movies about. But many scientists question whether the impact was the cause of this mass extinction.[49] This is primarily because dinosaurs were already on the decline and many groups of animals survived the event, including crocodiles, champsosaurs, turtles, birds, mammals, and many others.[50] There were volcanic eruptions in India sixty-five million years ago that would have blown massive amounts of volcanic ash and other particulates into the atmosphere. This would have disrupted climate and could have caused the extinction of many organisms. Also at the time, there was a significant drop in worldwide sea levels that would have altered habitats, changed climate, and had a major impact on life. It should be noted that four other major extinctions, and several "minor" ones, had occurred on Earth before the K-T boundary extinction. One of these, at the Permian-Triassic boundary about 250 million years ago, was even more devastating, wiping out about 95 percent of all species on Earth. Paleontologist David Raup once reflected, "If these estimates (of the number of species that became extinct at the Permian-Triassic boundary) are even reasonably accurate, global biology had an extremely close brush with total destruction."[51]

In the end, the cause or causes of the K-T boundary extinction are perhaps not as important as the result, for it paved the way for development of new life on Earth, particularly the evolution of mammals. The Paleocene (first epoch of the Tertiary Period) was a period of recovery and renewal, when the world began rebounding from this biological catastrophe.

North Dakota Everglades

North Dakota Heritage Center



Map by Brian R. Austin

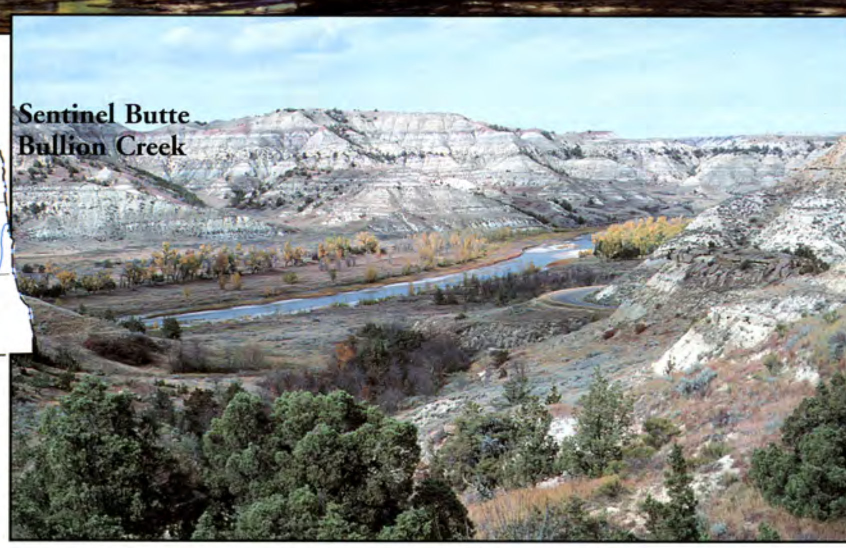


Photo by John Hoganson

Swampland habitat during the Paleocene sixty million years ago in western North Dakota. Crocodiles, crocodile-like champsosaurs, and several kinds of turtles, fish, insects, and mollusks lived in these swampy areas. Exotic plants such as bald cypresses, dawn redwoods, magnolias, ginkgos, and palms grew here, and mammals and birds lived in the forested swamplands. Farther east in North Dakota the Cannonball Sea was inhabited by sharks, rays, and ratfish. Left: Map showing location of Paleocene formations. Right: Outcrops of the Paleocene Bullion Creek and Sentinel Butte Formations, Theodore Roosevelt National Park, South Unit, Billings County. Far upper right: Sandstone and mudstone outcrop of the Paleocene Cannonball Formation along the Heart River near Mandan, Morton County.

Photo by Ed Murphy

At the beginning of the Paleocene, about sixty-five million years ago, warm, shallow oceans covered much of central and eastern North Dakota, and huge forested swamplands similar in many ways to today's Florida Everglades existed in the western part of the state. Plant fossils indicate that the climate was warm-temperate to tropical, again probably resembling that of the present-day American Southeast. During the early Paleocene in North Dakota temperatures were mild, averaging about 50°F; by the late Paleocene mean annual temperature has been estimated to be 65°F, with winter temperatures no colder than 55°F.[52]

During this time, sediments eroded from the rising Rocky Mountains were carried by rivers to western North Dakota and deposited in river channels and floodplains. Volcanic ash, generated by volcanoes in the western part of the country, was occasionally blown as far east as North Dakota and deposited on the landscape and in the lakes and swamps. The sediments turned into sandstone, siltstone, mudstone, claystone, and lignite, and are referred to as the Ludlow, Slope, Bullion Creek, Sentinel Butte, and Golden Valley Formations. These layered and multicolored rock formations, some of them several hundred feet thick, create the beautiful landscape in the northern part of the Little Missouri National Grasslands, seen most dramatically in Theodore Roosevelt National Park. In central and eastern North Dakota, sediments deposited in the Cannonball Sea—as the waters occupying the Western Interior Seaway at this time have been designated—formed sandstones and mudstones. The sandstones were laid down in the shallow marine and shoreline areas, and the mudstones in deeper water. These deposits are called the Cannonball Formation.

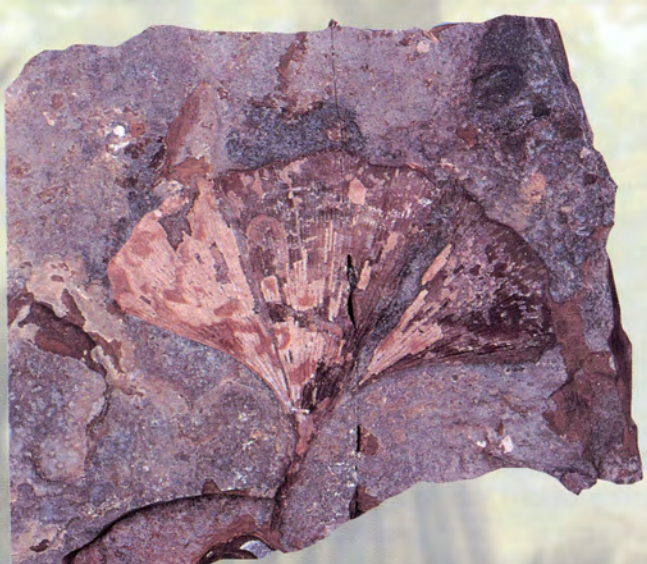
The hot, humid, swampy lowlands of western North Dakota provided habitat for many exotic plants and animals. Lush forests filled with ferns, cycads, figs, bald cypresses, magnolias, ginkgos, sycamores, dawn redwoods, palms, and other subtropical plants flourished. Water lilies and *Equisetum* (horsetail) grew in the ponds and swamps. Mats of vegetation dozens of feet thick built up in the swamps; after millions of years of pressure and heat, the plant

Fossils indicate that during the Paleocene much of western North Dakota was covered by lush forests containing ferns, redwoods, palms, and other subtropical plants. All fossils shown here are from the Sentinel Butte Formation.

Dawn redwood cone
Metasequoia
Morton County
Length 78 mm
ND 186.40

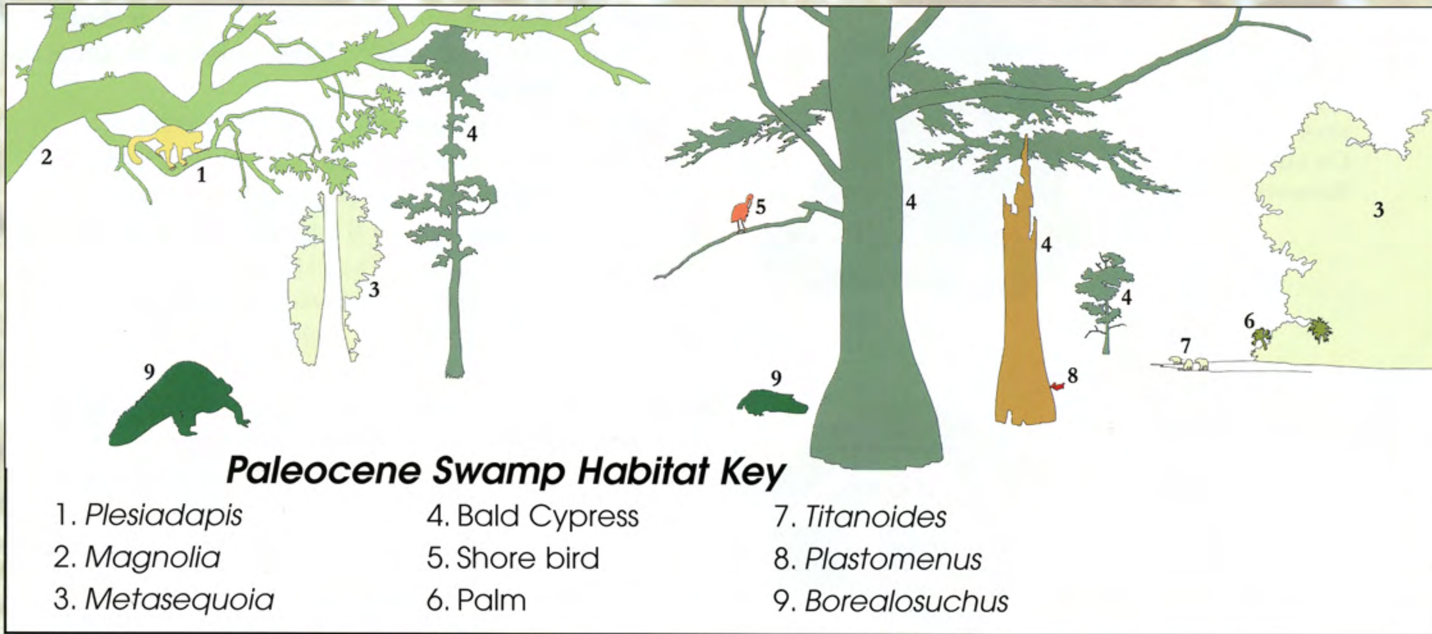
Dawn redwood leaf
Metasequoia
McLean County
Length 84 mm
ND 92-15.30

Birch flower cluser
Palaeocarpinus
Morton County
Length 49 mm
ND 03-38.116



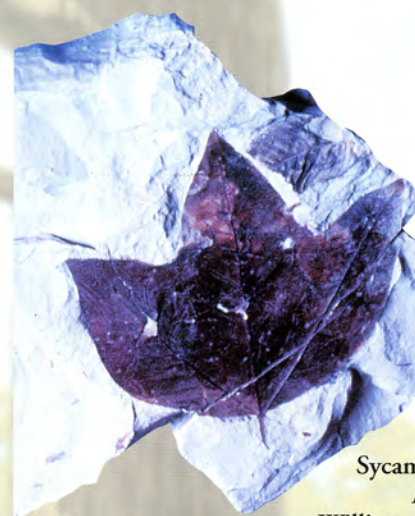
***Ginkgo* leaf**
Morton County
Width 81 mm
ND 447.3

Fern
McLean County
Length 107 mm
ND 183.1



Key by Brian R. Austin

Walnut seed cluster
Platycarya americana
Golden Valley Formation
Stark County
Length 56 mm
ND 92-91.11



Sycamore leaf
Platanus
Williams County
Width 150 mm
ND 92-59.1

Katsura tree fruits
Cercidiphyllaceae
Morton County
Width 58 mm
ND State Fossil Collection

Winged seed similar to modern maple
Morton County
Width 41 mm
ND 03-38.84

Horse chestnut leaf
Aesculus hickeyi
Williams County
Length 195 mm
ND 92-59.8

Walnut nut
Cyclocarya
Morton County
Length 28 mm
ND 03-39.8

**Bivalve (mussels) and *Campeloma* (snail)
Billings County
Width 63 mm**
ND 95-124.1
On exhibit at Theodore Roosevelt National Park

**Pill Clam
McKenzie County
Width 5 mm**
ND 97-108.10
On exhibit at Theodore Roosevelt National Park

**Land Snail
Planorbis planoconvexus
Mercer County
Width 34 mm**
ND 92-15.40

Invertebrate animals such as pill clams, mussels, snails, insects, and minute crustaceans lived in North Dakota's rivers, streams, ponds, and swamps. All fossils shown here are from the Sentinel Butte Formation.

material transformed into layers—some as thick as thirty feet (10 m)—of lignite coal.[53] Dense forests extended as far north as the Arctic Ocean.[54]

Many kinds of vertebrates lived in and around the aquatic habitats of western North Dakota. The last dinosaurs had become extinct by the Paleocene Epoch, but the primary predators were still reptiles: crocodiles, alligators, champsosaurs, and turtles. The largest of these animals was the crocodile *Borealosuchus*. *Borealosuchus* grew to lengths of fifteen feet (4.5 m) and was similar in appearance to the living crocodile. The main predator at the time, it fed on turtles, champsosaurs, fish, birds, and mammals. Fossils of *Borealosuchus* have been recovered from many sites in North Dakota. At one remarkable site in Billings County called Wannagan Creek, the remains of about eighty *Borealosuchus* skeletons have been found in an area roughly the size of an ice hockey rink.[55]

Champsosaurus gigas was one of the now-extinct species of crocodile-like reptiles that inhabited North Dakota's ponds and swamps during the Paleocene. As suggested by its name, *Champsosaurus gigas* was the largest species of *Champsosaurus*, attaining lengths of about twelve feet (3.5 m). Although not a crocodile, it resembled the living long-snouted gavial crocodilians that are found in India today. Because of its hydrodynamic body, powerful back legs, and long snout lined with sharp, pointed teeth, it is believed that *Champsosaurus gigas* was an aggressive underwater predator that fed on fish. These animals likely spent much of their

Photo by Brian R. Austin

Left: Detail from mural of Paleocene swamp habitat showing *Borealosuchus*.

Above: Reconstructed skeleton of a four-and-a-half foot (1.5 m) *Borealosuchus*. ND 408.1

Painting by Jerome Connolly, courtesy of the Science Museum of Minnesota, St. Paul

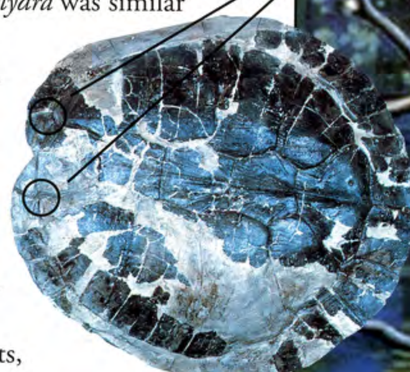
Left: As shown in this habitat reconstruction, *Champsosaurus gigas* was an underwater predator that used its powerful back legs to lunge off the bottom after fish.

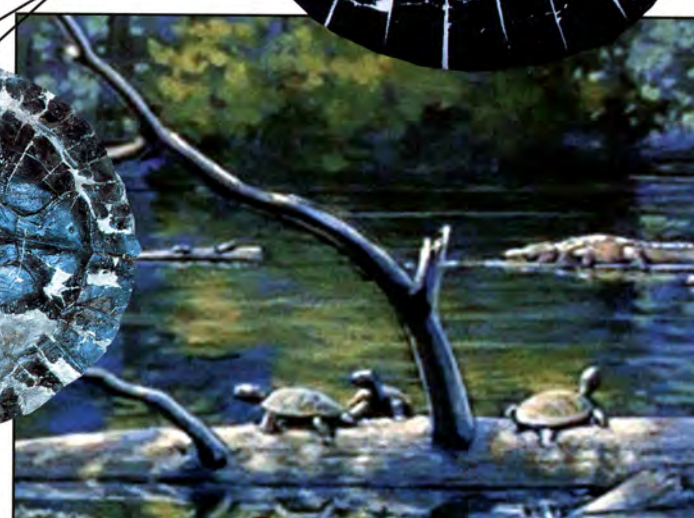
Below: Skeleton of the crocodile-like *Champsosaurus gigas.* ND 94-225.1

time submerged in water, lying on the bottom waiting for prey. When a fish swam by, the champsosaur would quickly lunge off the bottom after it, propelled by its large, powerful back legs.

Soft-shelled (*Plastomenus*) and snapping (*Protochelydra*) turtles also inhabited the Paleocene swamps and ponds. *Plastomenus* was similar to soft-shelled turtles that live today. It grew to lengths of about eighteen inches (46 cm) and had a low, rounded shell. Unlike most other turtles, soft-shelled turtles do not have a true horny covering; instead, the underlying bony plates are covered with a layer of soft, leathery skin. *Plastomenus* had a long, mobile neck. It was probably omnivorous and would have eaten plants, insects, mollusks, and even small fish. *Protochelydra* was similar to the living snapping turtle. Its shells, about twenty-four inches (60 cm) long, look much like those of its modern relatives. Like today's snapping turtle, it was carnivorous, with fish probably being the main part of its diet. Bite marks on some *Protochelydra* shells indicate that it was a prey of crocodiles.

Several kinds of fish lived in North Dakota's Paleocene aquatic environments, including dogfish (*Amia*), gars (*Lepisosteus*), and freshwater rays (*Myledaphus*). Remains of snakes, frogs, varanid (monitor) lizards, and giant salamanders (*Piceoerpeton*) indicate that these animals were also part of this interesting swampland community. Bird fossils are extremely rare because bird bones are hollow and are not often preserved. However, bones of plover-like shorebirds and their tracks, as well as owls, have been found.[56] Insect fossils are equally scarce for the same reason. Nevertheless, the remains of mayflies, dragonflies, and beetles indicate that





Top: Shell of the soft-shelled turtle *Plastomenus.* Collected on USDA Forest Service-Dakota Prairie Grasslands-administered land, Sentinel Butte Formation, Billings County. Length 320 mm. ND 213.1 Above: Detail from mural of Paleocene swamp habitat showing *Plastomenus.* Left: Shell of the snapping turtle, *Protochelydra,* Sentinel Butte Formation, Billings County, length 370 mm, ND 94-186.1. Theodore Roosevelt National Park exhibit.

they thrived in the swampy habitat. Plant fossils showing damage from insect feeding have also been found.

Prior to the Paleocene, when dinosaurs dominated life on land, mammals were small (mouse- or rat-sized) and few in number. Some paleontologists believe this was because dinosaurs simply out-competed mammals during the Cretaceous.[57] But mammals quickly diversified after the final demise of the dinosaurs, occupying many of the niches vacated by their reptilian competitors. Very quickly, many new mammalian groups evolved in the warm, forested swamplands. This evolutionary radiation of mammals was unprecedented and spectacular in biological terms. There were eighty-four genera (major groups) of mammals in North America by the middle of the Paleocene, and one hundred by the late Paleocene, compared to just eighteen in the Late Cretaceous.[58] In fact, by the early Eocene, just ten to twelve million years after the Cretaceous-Tertiary boundary extinction, all orders of living mammals had evolved.[59]

Fossils of some of these mammals are found in Paleocene rocks in western North Dakota. One of the more interesting of them was *Plesiadapis*, a lemur-like mammal about two feet (60 cm) long, somewhat larger than a modern squirrel. It had a long tail, agile limbs with claws rather than nails, and eyes situated on the sides of its head. Structures of the skull indicate that it probably had a good sense of smell. *Plesiadapis* had long, clawed fingers and toes and was well-adapted for climbing trees in the swampy woodlands of Paleocene western North Dakota. It has been described as a primitive relative of primates, but unlike modern primates, *Plesiadapis* had a long snout, rodent-like jaws and teeth, and long, gnawing incisors separated by a gap from its molars. It probably occupied an ecological niche similar to that of squirrels today.[60]

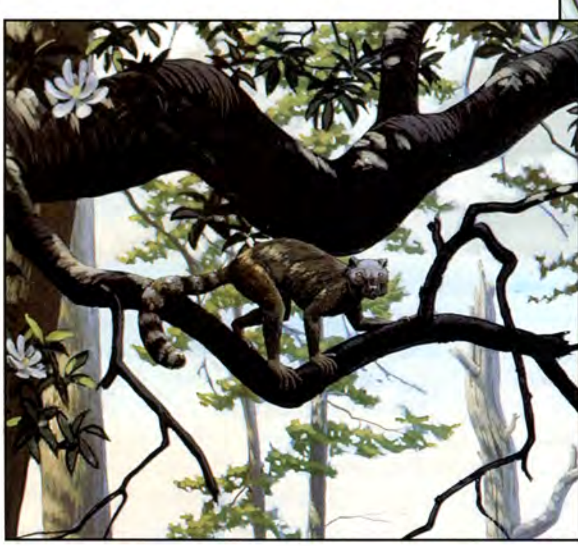
The swamps and ponds of the Paleocene supported a variety of fish and insects, as indicated by these fossils, all from the Sentinel Butte Formation. Evidence of insect feeding can be seen on the leaf fossil.

Leaf fossil with insect damage
Williams County
Length 76 mm
ND 92-59.29

Gar fish scale
Joffrichthys triangulpterus
Morton County
Length 4 mm
ND 98-1.1008

Gar fish jaw
Lepisosteus
Billings County
Length 46 mm
ND 94-225

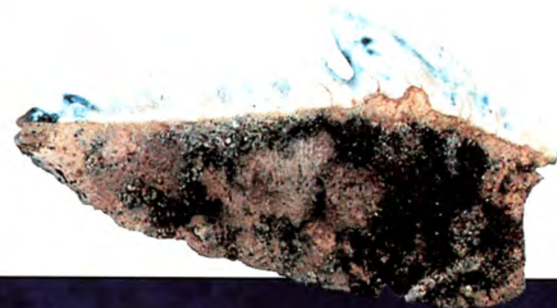
Photo by Brian R. Austin



Above: Skeleton (cast) of the lemur-like mammal *Plesiadapis* on a petrified log, length 60 cm, ND 06-03.1. Left: Detail of Paleocene swamp mural showing *Plesiadapis*.

The beginning of the Paleocene marked dramatic changes in the shallow oceans occupying much of central and eastern North Dakota, as well as in the swampy lowlands to the west. These changes are reflected in a new name for the waters occupying the Western Interior Seaway: the Cannonball Sea. The fossils found in the Cannonball Formation, the name given to the lithified sediments deposited in that sea, do not include mosasaurs and plesiosaurs, the large marine reptiles that lived in the Cretaceous seas, because they had become extinct at the end of the Cretaceous along with the dinosaurs. Instead, the main predators in the Cannonball Sea were new species of sharks. The most common shark found in the Cannonball Formation is *Carcharias*.[61] As noted earlier, generally the only fossils found from sharks and other fish with cartilaginous skeletons are teeth and dental plates. *Carcharias*, one of the main predators in the Cannonball Sea, was well adapted for ripping into the flesh of prey with its long, slender, sharp teeth. The ten-foot-long (3 m) shark undoubtedly patrolled the sea's shorelines, competing with other sharks for prey. *Carcharias* still lives today in temperate to tropical oceans, generally inhabiting shallow coastal waters.

Rays and ratfish were also common in the Cannonball Sea.[62] *Myliobatis* resembled the modern eagle ray, while *Dasyatis* looked like today's stingrays. Both had numerous small, flat teeth that were tightly arranged in the mouth to produce a crushing surface for breaking open the shells of clams, snails, crabs, and other animals. Some rays, including *Myledaphus bipartitus*, also lived in fresh- and brackish-water environments. Ratfish such as *Ischyodus* were likewise shallow marine dwellers that could crush shells with their powerful jaws. These were strange-looking fish with faces resembling a rat's. *Ischyodus* was small, up to about three feet (1 m) long, with large eyes, pursed lips, a tall dorsal fin, fanlike pectorals, and a whiplash tail. It crushed shells not with teeth but with hard dental plates. As in today's warm,



Shark tooth
Notorynchus serratissimus
Burleigh County
Width 36 mm
UND 15809

Painting by and courtesy of Richard Ellis

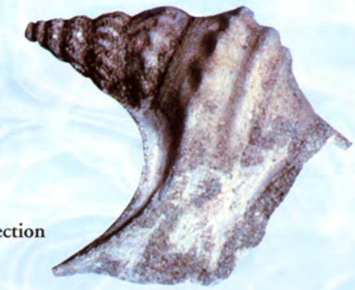
Shark tooth
Otodus obliquus
Burleigh County
Height 31 mm
UND 15807

Shark tooth
Carcharias taurus
Burleigh County
Height 27.4 mm
UND 967

Shark tooth
Megasqualus orpiensis
Bowman County
Width 2.9 mm
UND 15817

The shark *Carcharias* was the most common predator of the Cannonball Sea in North Dakota. Fossil teeth of *Carcharias* and other sharks have been found in the Cannonball Formation. These teeth are identical to those of the modern sand-tiger shark pictured above.

Coral
Paracyathus
Morton County
Height 15 mm
ND 391



Gastropod
Drepanochilus
Morton County
Height 22 mm
ND State Fossil Collection

Gastropod
Semitriton
Burleigh County
Height 33 mm
ND 385

Bivalve
Glycymeris
Morton County
Width 29 mm
UND 9527

Teredo clam and tube

Teredo-bored petrified wood
North Dakota State Fossil
Cannonball Formation
Morton County
Width 166 mm
SHSND 12151

Crab
Camarocarcinus arnesoni
Burleigh County
Width 56 mm
ND 376.1

Cephalopod
Hercoglossa ulrichi
Morton County
Width 174 mm
UND A2132

Lobster claw
Nephrops
Morton County
Length 85 mm
UND

Stingray tooth
Dasyatis concavifoveus
Bowman County
Width 1.8 mm
USNM 456243

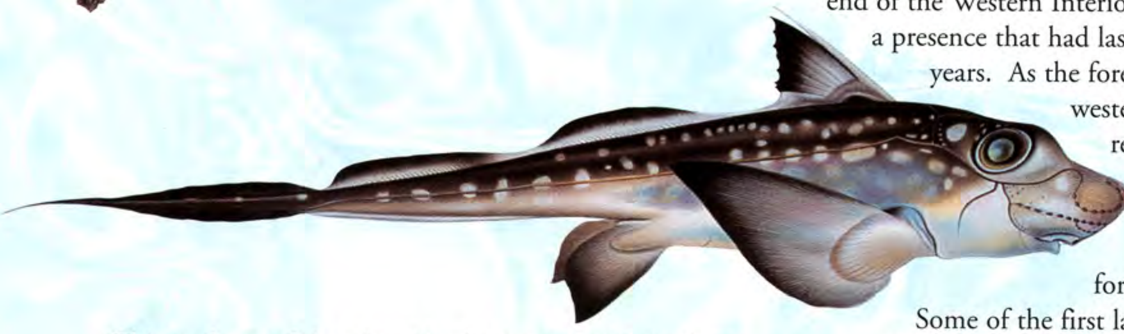
Ratfish upper dental plates
Ischyodus dolloi
Morton County
Length 30.5 mm
UND 15801

shallow oceans, fish with skeletons made of bone were also abundant in the Cannonball Sea; many fossils from these animals have been found in North Dakota.

The shallow-water and shoreline areas of the Cannonball Sea were also havens for diverse communities of warm-water invertebrate animals. Fossils of hundreds of species have been recovered from the Cannonball Formation, including corals, cephalopods, bivalves, gastropods, crabs, lobsters, bryozoans (small animals that form colonies similar to corals), echinoids (sea urchins), and starfishes.[63]

Teredo-bored petrified wood, North Dakota's state fossil, likewise occurs in the Cannonball Formation. This is driftwood that had been bored into by shipworms (clams) before becoming petrified. The borings in the petrified wood resemble sinuous tubes. Collectively, the fossils found in the Cannonball Formation indicate that the Cannonball Sea was shallow and its water warm.

About sixty million years ago, the Cannonball Sea receded from all of North Dakota, marking the end of the Western Interior Seaway's presence in the state, a presence that had lasted about one hundred million years. As the forests and swamps that covered western North Dakota spread over the remainder of the state, the animals also spread east, including the new mammalian groups that were rapidly filling the niches formerly occupied by dinosaurs.



This modern ratfish, painted by B. Deane (1906), is about three feet (1 m) long. The mouth of a ratfish contains bony plates used to crush shellfish. The fossil ratfish palate shown above contains two dental plates that form the roof of the animal's mouth.

Some of the first large mammals to leave a fossil record in North Dakota lived in these dense forests of the Paleocene Epoch.

The largest mammal that inhabited North Dakota sixty million years ago was *Titanoides*, one of the early Cenozoic browsing mammals called pantodonts. Bearlike in appearance, *Titanoides* had short, stout limbs and feet with five clawed digits. Even though it had huge canine tusks, its limbs—adapted for digging roots—and the shape of its cheek teeth indicate that it was a herbivore. It is likely that *Titanoides* at times fell prey to crocodiles, the main predators at the time. The largest mammalian predators during the Paleocene were only the size of small dogs.

Eagle ray tooth
Myliobatis
Above: root view of tooth
Below: crown view of tooth
Bowman County
Width 35.2 mm
UMMP 53784

The global warming during the Paleocene continued into the early Eocene, fifty-five million years ago. Plant fossils from the Golden Valley Formation in North Dakota and elsewhere in the upper Midwest indicate mean annual temperatures as high as 65°F. [64] In comparison, western North Dakota today has a cold, dry grassland climate with a mean annual temperature of 41°F. In contrast to today's grasslands, dense tropical forests similar to those in Central American areas like Panama today grew in North Dakota during the early Eocene.[65] These greenhouse conditions extended into the Arctic, with palm trees and cycads growing in Alaska and alligators living in the Canadian

Arctic.[66] North Dakota was a hot, humid, densely forested, swampy lowland transected by sluggish streams. The state was likely frost free. Several species of aquatic plants, ferns, herbs, shrubs, vines, and trees (including palms) grew in this forested swampland.[67] The diverse animal community that inhabited the area consisted of fish, amphibians, reptiles (e.g., turtles, lizards, crocodiles, and alligators), birds, and mammals including insectivores, rodents, the early horse "*Hyracotherium*," the large tapir-like pantodont *Coryphodon*, and carnivores.[68]

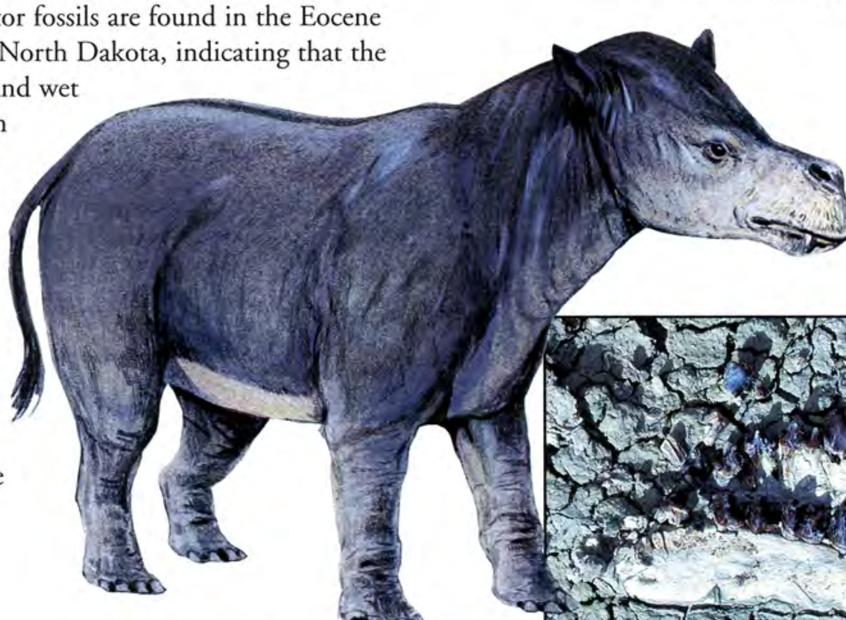
During the early Eocene there was a major migration of mammals into North America from Asia. One such immigrant was *Coryphodon*, the largest mammal—up to about eight feet (2.5 m) long—that lived in North Dakota at this time. Bulky and slow-moving, it was similar in some ways to the hippopotamus. *Coryphodon* was probably semi-aquatic; it dug up swamp plants with its canine tusks, although it also browsed on forest vegetation. For its size, *Coryphodon* had an extremely small brain, the smallest ratio of brain to body weight in any mammal.

The early Eocene greenhouse conditions gradually came to an end by the early Oligocene, about thirty-five million years ago. During this time there was a worldwide climate cooling that resulted in the formation of ice sheets on Antarctica.[69] It has been estimated that global temperatures dropped by almost 22°F.[70] In North Dakota the equable, humid, warm-temperate to subtropical climate that had prevailed during the Paleocene and early Eocene became cooler and drier. The swampy environments of the Paleocene and early Eocene began to disappear, along with the plants and animals that had inhabited them. Alligator fossils are found in the Eocene Chadron Formation in North Dakota, indicating that the climate was still warm and wet enough to support them even though conditions were changing.[71] After that time these reptiles essentially disappeared from North Dakota, never to return. By the Miocene Epoch, about twenty-four million years ago, the climate here was cool-temperate and semiarid to arid, with pronounced dry seasons.

Photo by Brian R. Austin

Courtesy of National History Museum, London

Top: Crushed skull and lower jaws of the bearlike mammal *Titanoides*, Sentinel Butte Formation. Recovered from USDA Forest Service-Dakota Prairie Grasslands-administered land in Billings County. Length 300 mm. ND 98-38

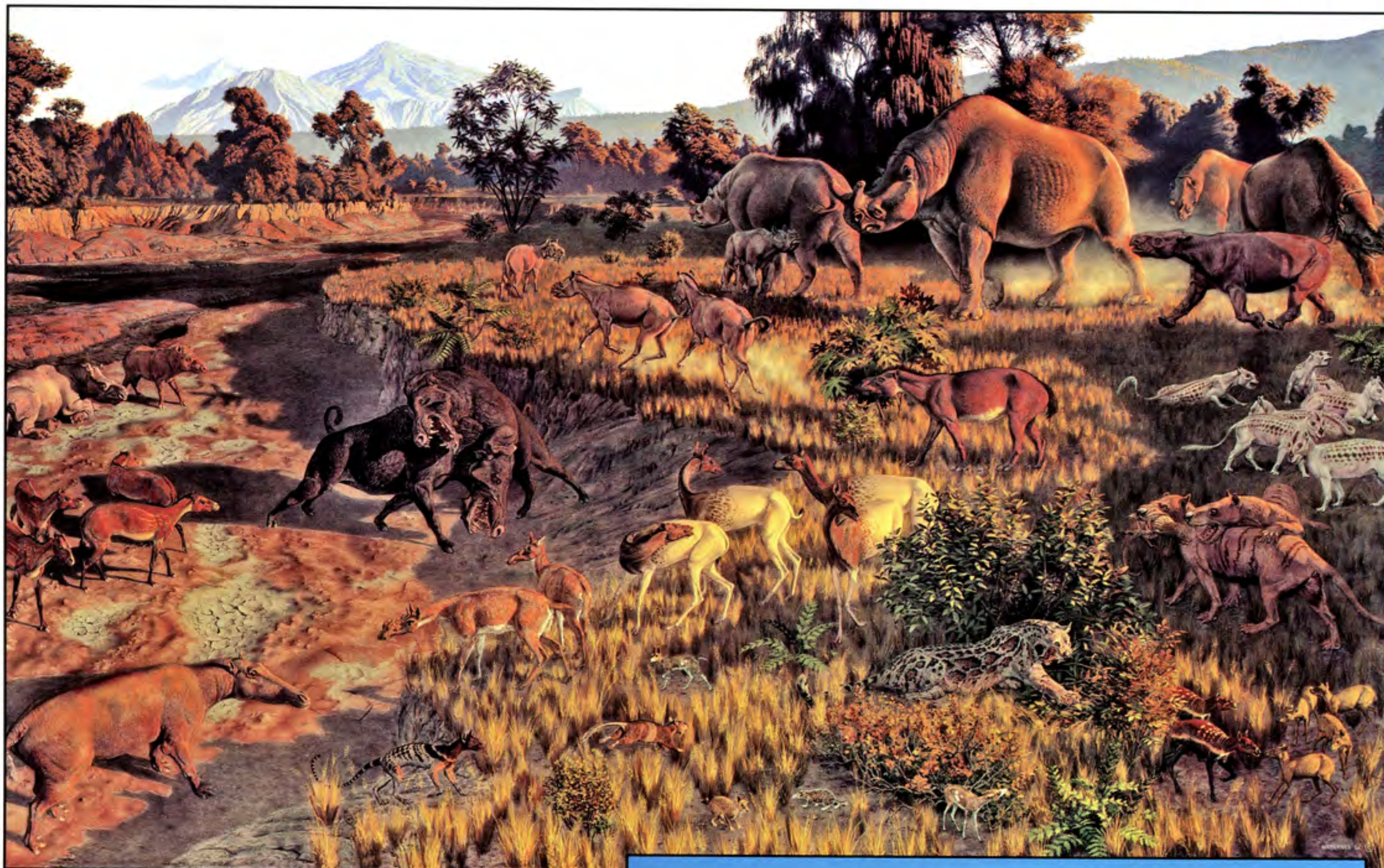


Courtesy of National History Museum, London

Photo by Allan Ashworth

Lower jaws of *Coryphodon* weathering out of the Golden Valley Formation, Stark County. Length 280 mm. NDSU

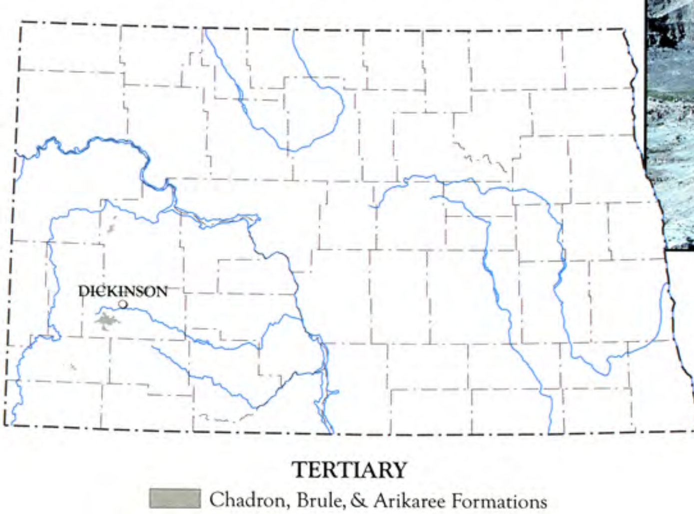
NORTH DAKOTA SAVANNA



Mural by J.H. Matternes, courtesy of Smithsonian Institution

Habitat reconstruction of a late Eocene/Oligocene mammal community.

Photo by John Hoganson



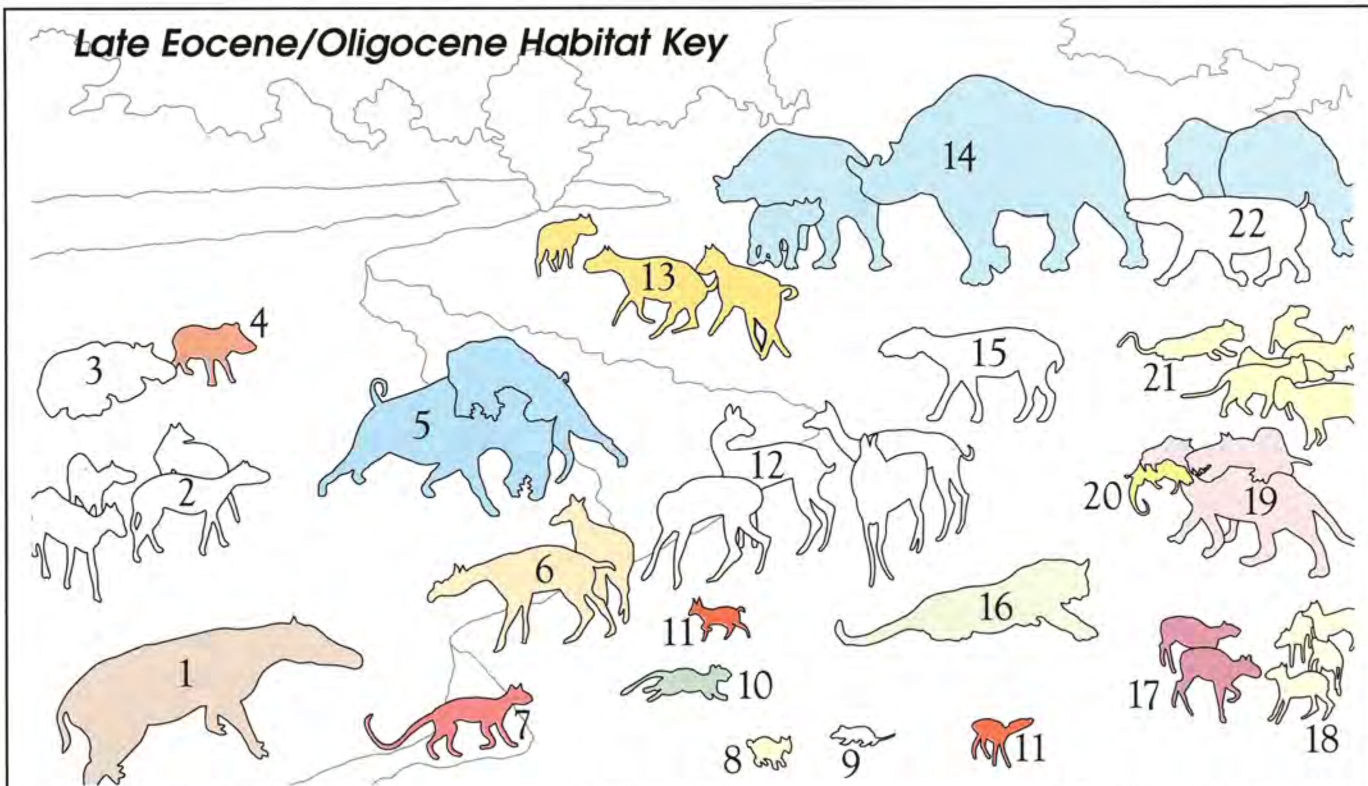
Map by Brian R. Austin

Left: Map showing Chadron, Brule, and Arikaree Formation outcrop areas in North Dakota. Above: Outcrops of the Oligocene Brule Formation, Little Badlands, Stark County.

By the Oligocene, about thirty million years ago, the subtropical, swampy forests had given way to a mostly treeless plain, similar to a savanna, in North Dakota. This open plain was a scrubland consisting of shrubs, herbaceous plants, and possibly some grasses. True savanna habitats, dominated by grasslands similar to parts of Africa today, did not become established in the state until the Miocene. The Oligocene climate was seasonal and temperate, with an annual rainfall similar to that in the state today. Ponds and lakes punctuated the open plain, and gallery woodlands grew along the margins of streams and rivers. Rivers flowed across the plain, depositing sand and gravel in their channels. There were seasonal droughts and floods, with the latter spreading silt and mud over vast floodplain areas. Layers of volcanic ash in the rocks indicate that volcanoes were active in the western part of the continent. Sediments deposited in these ways, now lithified, are the Chadron (Eocene), Brule (Oligocene), and Arikaree (Miocene) Formations.[72] These rocks have mostly eroded away in North Dakota, but remnants of them cap many buttes in the western part of the state; one spot where they are exposed is the Little Badlands of Stark County.

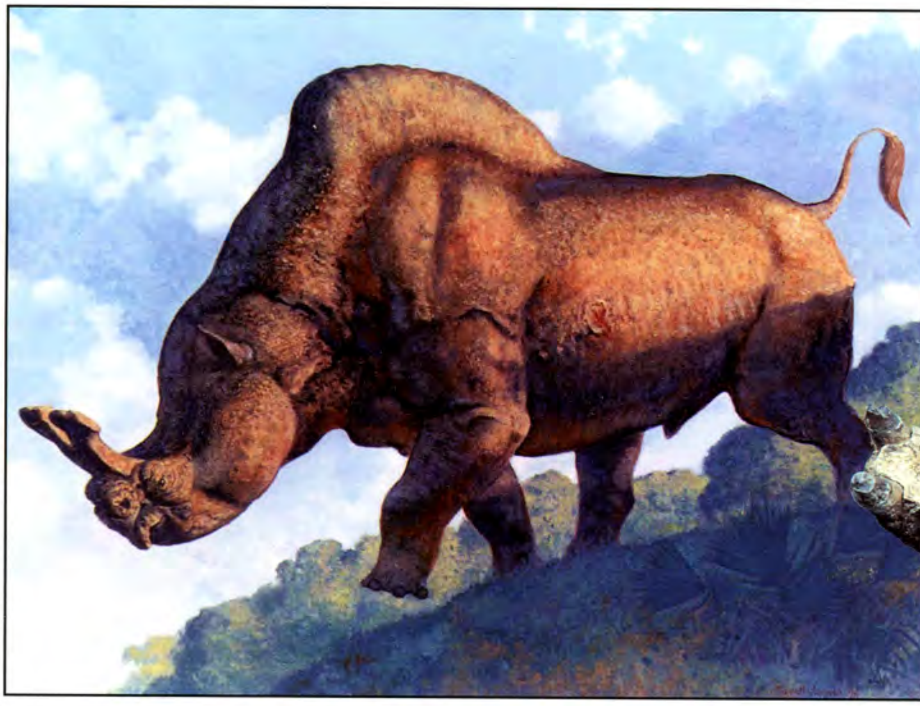
The most spectacular mammals that lived during the late Eocene in North Dakota were the brontotheres. The size of elephants, about eight feet (2.5 m) tall at the shoulder, they were some of the largest mammals ever to live in North Dakota. They are also call titanotheres, or "thunder beasts," because of their immense size. Brontotheres resembled rhinoceroses and browsed on the soft forest vegetation in the dry woodlands of that period.[73] The large, bony knobs on their snouts, which were probably covered with skin as in modern-day giraffes, were used for display or as weapons during fights among males to establish dominance. Fossils of these animals are found in the Chadron Formation.[74] Brontotheres lived during the transition from warm swampland to cooler open-plain conditions, and apparently they did not survive this change because their fossils are not found in the younger Oligocene Brule Formation. Other plants and animals also became extinct at this time.

Fossils recovered from the Brule Formation show that the number of mammal species, mostly adapted for grazing, and the abundance of mammals dramatically increased in



1. *Aepinacodon*
2. *Mesohippus*
3. *Trigonias*
4. *Perchoerus*
5. *Archaeotherium*
6. *Protoceras*
7. *Hesperocyon*
8. *Palaeolagus*
9. *Leptictis*
10. *Ischyromys*
11. *Hypisodus*
12. *Poebrotherium*
13. *Hyracodon*
14. *Brontotherium*
15. *Protapirus*
16. *Hoplophoneus*
17. *Leptomeryx*
18. *Hypertragulus*
19. *Hyaenodon*
20. *Glyptosaurus*
21. *Merycoidodon*
22. *Subhyracodon*

Key by Brian R. Austin



Painting by and courtesy of Dan Varner

Brontops, a member of the group of large rhinoceros-like mammals called brontotheres, browsed on soft forest vegetation and was one of the largest mammals ever to live in North Dakota.

Below: *Brontops* lower jaws, Chadron Formation, Eocene, Bowman County, length 410 mm. UND D-232

the warm-temperate, dry, open-plain Oligocene habitats in North Dakota following the Eocene extinctions. Most of these mammals migrated to North America from Asia as a result of a drop in sea level caused by climate cooling and glacier development.[75] These immigrants were ancestral members of families that still exist today, including dogs, cats, camels, deer, squirrels, beavers, horses, rabbits, rhinoceroses, and mice.[76] Fish, turtles, lizards, amphibians, birds, insects, gastropods, and bivalves also lived in North Dakota during this time. Many of these animals preferred to occupy specific habitats within the open plain and associated woodlands.

Although there were no dense forests (and thus few tree-dwelling mammals like primates), sparse gallery woodlands grew along the waterways and other water bodies. We know little about the flora of these riparian forests because few plant fossils have been found. Calcified seeds of hackberry trees (*Celtis*) are present, indicating that this tree grew here during the Oligocene. The sparse forests appear to have been the favored habitat of several mammals, although surely these creatures would have roamed the open plains, too. The largest of these were the the giant pig-like *Archaeotherium*, the hippo-like *Metamynodon*, and *Subhyracodon,* one of the early rhinoceroses. Tapir-like in

Rhinoceros skull, *Subhyracodon occidentalis*, Brule Formation, Oligocene, Stark County, length 520 cm. The Manitoba Museum.

Photo by John Hoganson

Excavation of a *Subhyracodon* skeleton, Brule Formation, Stark County, with the ribs of the *Subhyracodon* exposed.

appearance, *Subhyracodon* had short, stout limbs, four-toed front feet, and three-toed hind feet. It had a large, hornless head and grew to lengths of about eight feet (2.5 m). *Subhyracodon* was a plant-eater that lived in herds.

Archaeotherium belonged to the group of pig-like mammals called entelodonts. It was similar in appearance to the living warthog and grew to about four feet (1.2 m) long. It had an elongated skull, with unusual protrusions of bone beneath the eyes. These bony knobs probably provided attachment points for the powerful jaw muscles. *Archaeotherium* mostly ate roots and tubers, but with its powerful jaws and teeth it could have eaten most anything, even carrion; in this sense it was like modern-day pigs. These animals had strong shoulder and neck muscles, as indicated by their bone structure. They may have spent much of their time rooting and grubbing in the ground. Large olfactory lobes suggest that they had a keen sense of smell.

Another pig-like mammal, *Merycoidodon,* and the diminutive horse *Mesohippus* were among the most common animals that lived in North Dakota during the Oligocene. They frequented the forests along the streams and also roamed the open plains. *Merycoidodon* was a member of the now-extinct family Merycoidodontidae, and are also sometimes referred to as oreodonts. These animals had some features that are typical of pigs and others that are typical of camels. They possessed advanced teeth, with long-lasting grinding surfaces adapted for effective side-to-side chewing of vegetation. *Merycoidodon* was sheep-sized, about four feet (1.2 m) long, but probably looked more like a pig or peccary. It was heavily built, with short legs and four-toed feet, and was not an efficient runner. Fossils of

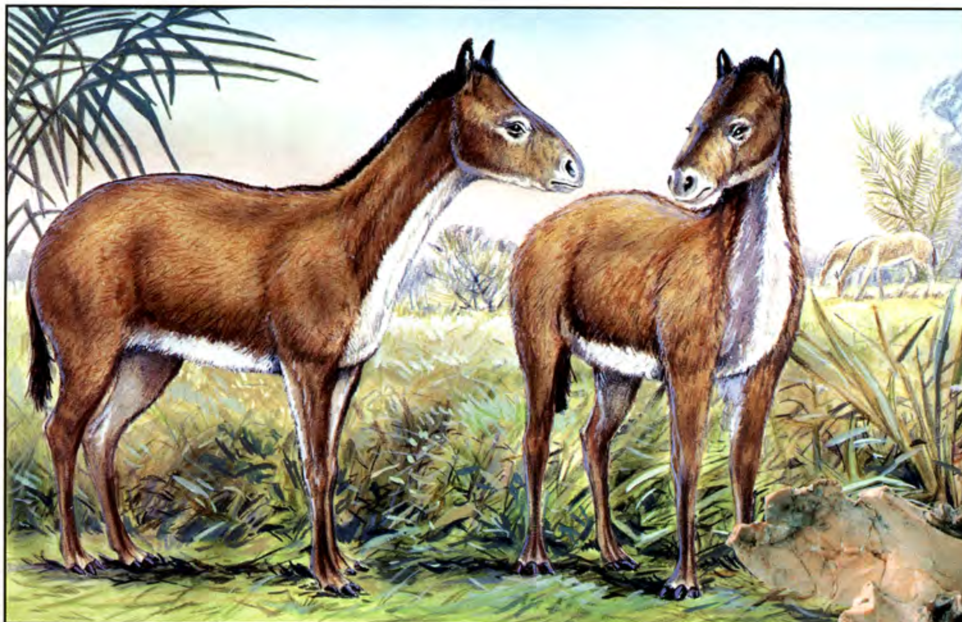
Courtesy of Marshall Editions Ltd.

The bony knobs below the eyes of *Archaeotherium* probably provided attachment areas for the powerful jaw muscles. The strong shoulder and neck muscles suggest that these animals spent much of their time rooting and grubbing in the ground for food.
Top: Skull and lower jaws of *Archaeotherium*, Brule Formation, Stark County, length 435 mm. MM V-1766

Courtesy of Marshall Editions Ltd.

***Merycoidodon* was about four feet (1.2 m) long and probably looked somewhat like a pig. It roamed in large herds.**

Left: Skull and lower jaws of *Merycoidodon culbertsoni*, Brule Formation, Oligocene, Stark County, length 198 mm. ND 303.1



Painting by Michael R. Long, courtesy of the Natural History Museum, London

Mesohippus, one of the early species of horses, was about the size of a greyhound dog. It had slender limbs adapted for trotting and running.

Below: Lower jaws of *Mesohippus*, Brule Formation, Oligocene, Stark County, length 135 mm. The Manitoba Museum.

Bottom: Skeleton (cast) of *Mesohippus bairdi* on exhibit at the North Dakota Cowboy Hall of Fame Museum in Medora, Brule Formation, height 465 mm.

Photo by Brian R. Austin

Merycoidodon are common, indicating that these browsing animals lived in large herds.

Mesohippus was one of the early species of horses. It superficially resembled the modern horse, except that it was much smaller—only around two feet (60 cm) tall at the shoulder, and up to four feet (1.2 m) long. It was about the size of a greyhound dog. *Mesohippus* had slender limbs adapted for trotting and running. It had three toes on each foot, in contrast to the modern horse, which has one. Another difference between *Mesohippus* and today's horse is that *Mesohippus* teeth were low-crowned and therefore suited for browsing leaves from bushes and trees, whereas teeth of a modern horse are high-crowned and suited for grazing primarily on grasses.

Other mammals that inhabited the wooded areas during the Oligocene were the squirrel-like rodent *Ischyromys*, the rabbit *Palaeolagus*, and the beaver *Agnotocastor*. *Ischyromys* is one of the earliest of the true rodents. Similar in appearance to today's rodents, it had a characteristic pair of upper incisors, as well as other rodent head features. Its strong hind limbs, with five clawed toes on each of its hind feet, were also like those of modern rodents. *Ischyromys* grew to lengths of two feet (60 cm). It is believed to have been an efficient tree climber, like today's squirrels.

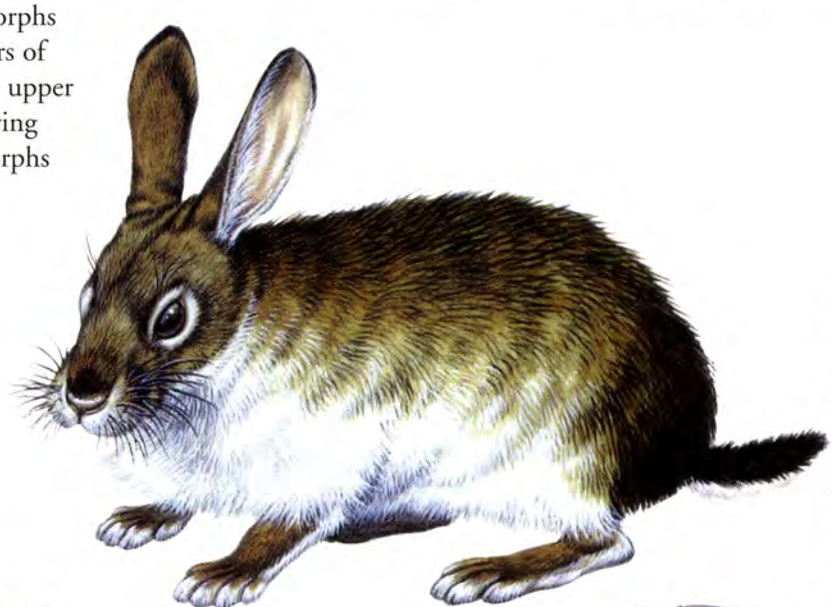
Courtesy of Marshall Editions Ltd.

Ischyromys is one of the earliest of the true rodents. Right: Lower jaw of *Ischyromys*, Brule Formation, Stark County, length 20 mm. ND 248

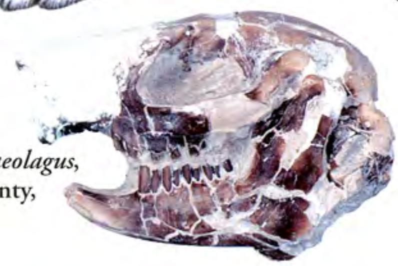
Palaeolagus is in the Lagomorpha family, which includes pikas, rabbits, and hares. Because of their small size and continually growing incisors (gnawing teeth), lagomorphs are much like rodents, except that they have two pairs of incisors—one immediately behind the other—in the upper jaws compared to a single pair in rodents. The chewing action is also different in the two groups. In lagomorphs the jaws work sideways, in rodents backwards and forwards. *Palaeolagus* was similar in appearance to the modern rabbit except that its hind legs were proportionally shorter, which suggests that it was better adapted for scampering than for hopping. *Palaeolagus* grew to lengths of about ten inches (25 cm).

Large tortoises (*Stylemys*) and other turtles such as the soft-shelled *Trionyx* and *Testudo* lived in and around streams, ponds, and lakes during this time. *Stylemys* is in the family of dryland tortoises, the last major group of turtles to appear in the fossil record. It was similar to the modern Galapagos turtle. *Stylemys* grew to lengths of four feet (1.2 m) and had a high, domed shell and large legs. It was a herbivore. Its frequent presence in the Brule Formation indicates dry conditions were prevalent during the Oligocene. *Trionyx*, which inhabited ponds and quiet stream-marginal areas, was similar to the soft-shelled turtles that live today. Unlike most other turtles, *Trionyx* did not have a horny covering; instead the underlying bony plates were covered with a layer of soft, leathery skin. It probably fed on plants, insects, mollusks, and even small fish.

Palaeolagus grew to lengths of about ten inches (25 cm) and was similar in appearance to the modern rabbit.



Courtesy of Marshall Editions Ltd.



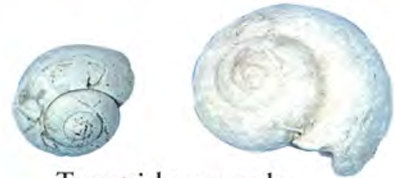
Skull and lower jaws of _Palaeolagus_, Brule Formation, Stark County, length 51 mm. ND 146.1

Trionyx turtle skull, Brule Formation, Stark County, length 65 mm. ND 97-116.2

Tortoise shell, _Stylemys nebrascensis_, Brule Formation, Stark County, length 226 mm. MM V-1931

Trionyx turtle shell, Brule Formation, Stark County, length 230 mm. ND 97-116.3

Plioplarcus fish skeleton, Eocene, Chadron Formation, Golden Valley County, length 80 mm. ND 421.1



Terrestrial gastropods, *Skinnerelix leidyi*, Brule Formation, Stark County, width of largest 27 mm. ND 314.1, 314.2

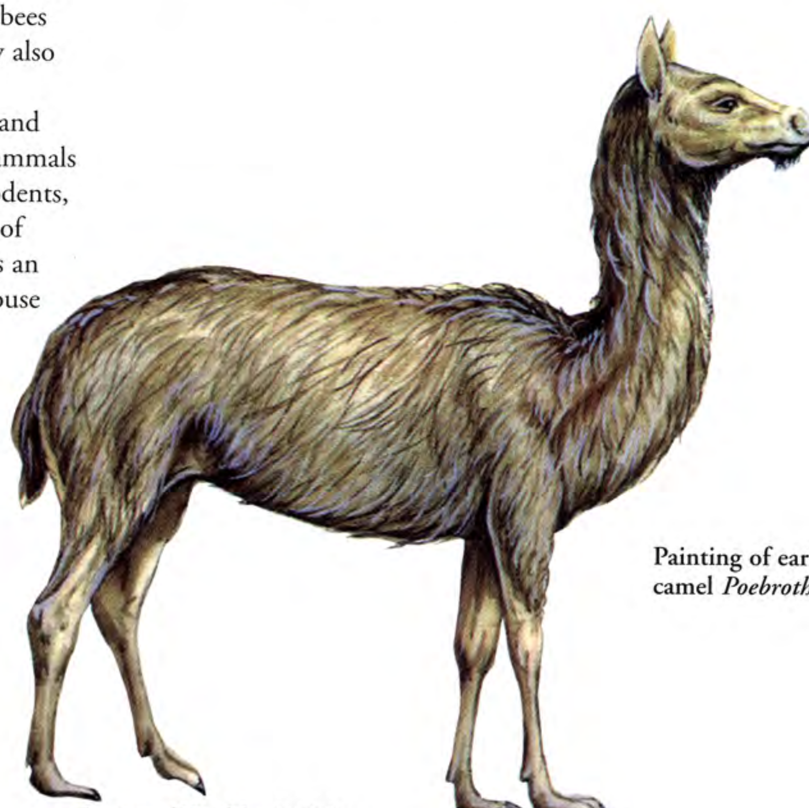
Skull of the rodent *Eumys*, Brule Formation, Stark County, width 51 mm. ND 271.3

Beetle pupal cells *Pallichus dakotensis* Brule Formation, Stark County, width of largest 20 mm. ND 363.1, 363.2, 363.3

Fish were common in the aquatic habitats, too. Spectacular fossil skeletons of the perch *Plioplarcus* have been found in the Chadron Formation. Remains of land snails, including pupillids and the large-shelled *Skinnerelix* (which could be called "Oligocene escargot"), pupal cells of burrowing beetles (*Pallichus*), and larval cells of sweat bees (*Celliforma*) have been discovered, indicating that they also lived in the streamside woodlands.

While herds of larger mammals like *Merycoidodon* and *Mesohippus* also frequented the open plain, smaller mammals seem to have been more abundant in that habitat. Rodents, like *Eumys*, were particularly common, and the fossils of several species of rodents have been found. *Eumys* was an early representative of the highly successful rat and mouse group of rodents, which today includes hamsters and voles. In recent times this has become the most widespread and abundant group of rodents, indeed of all mammals.

The small, gazelle-like camel *Poebrotherium* and tiny deer *Leptomeryx* were also common dwellers of the plains. Camels first evolved in North America, and modern camels are the remnants of a formerly much more widespread and diverse group. *Poebrotherium* was one of these early camels. Lightly built and goat-sized, it was about three feet (90 cm) long. Its head, with a distinctive narrow snout, and long neck made it look similar to the modern-day llama. The slender hind legs of *Poebrotherium* were longer than its forelegs, and it had hoofed toes. It was an efficient runner. This animal had long jaws, and its forward-extending front teeth (a feature it shared with living camels) enabled it to snip off vegetation.



Painting of early camel *Poebrotheriu*

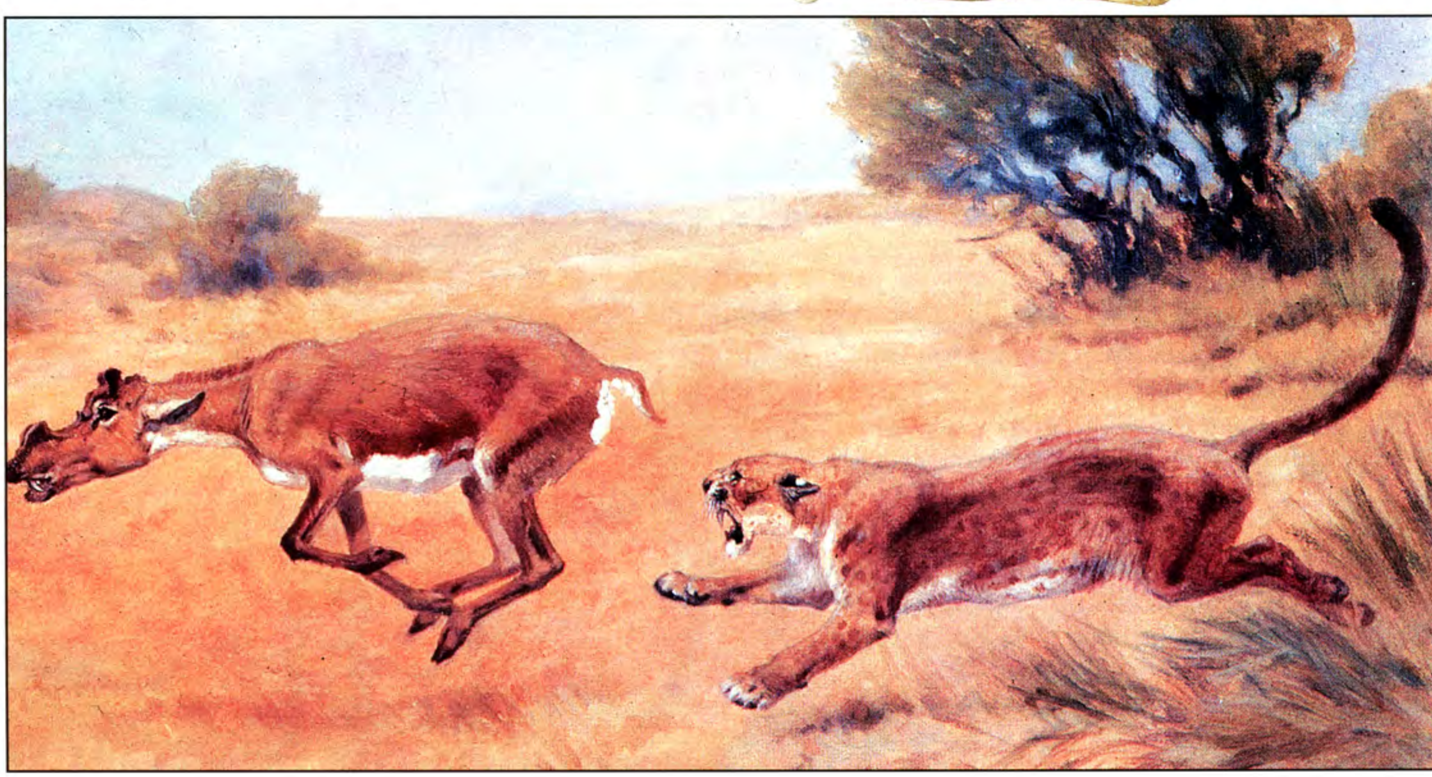
Courtesy of Kingfisher Publishing

Above: Skull of the small deer *Leptomeryx*, Brule Formation, Stark County, length 126 mm. ND 94-6.1
Right: Detail of *Leptomeryx* from Eocene/Ologocene mural.

Leptomeryx was a small, antler-less, cloven-hoofed deer about two feet (60 cm) long. Graceful and dainty, with long, slender limbs, it was no larger than a jackrabbit. *Leptomeryx* resembled the chevrotain or "mouse-deer" living in Asia today.

Herbivores greatly outnumbered carnivores on the North Dakota Oligocene plain, as is the case today on the African savannas. Nevertheless, fossils of several groups of carnivores and insectivores have been found in the Brule Formation. *Dinictis* was one of the early saber-toothed cats. Technically these were not true cats, belonging instead to a group of catlike carnivores known as mimravids. Their sleek, three- to four-foot long (1.2 m) bodies resembled that

***Dinictis* was one of the early saber-toothed cats. Its sleek, three- to four-foot-long (1.2 m) body, much smaller than the Ice Age *Smilodon*, resembled that of the present-day lynx. *Dinictis* was an extremely efficient predator. Right: *Dinictis* skull, Brule Formation, Stark County. Length 180 mm.** ND 05-67.1.

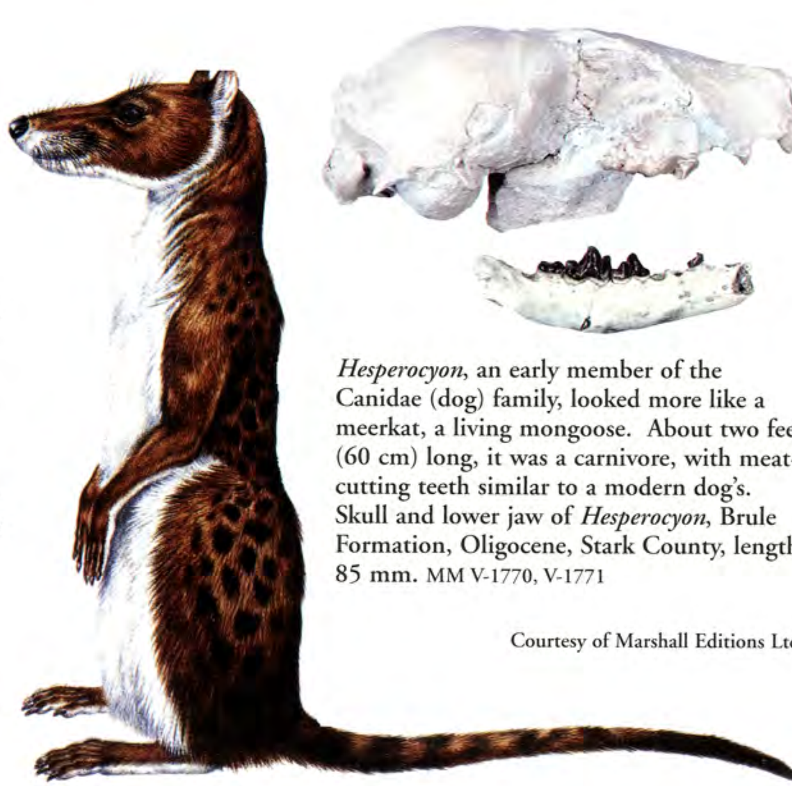


Painting by Charles R. Knight, courtesy of the American Museum of Natural History of the present-day lynx. They were much smaller than the huge saber-toothed cat *Smilodon* that lived during the Ice Age, only a few thousand years ago. *Dinictis* was an extremely efficient predator. Its upper canine teeth, like those of saber-toothed cats, were elongate, serrated, and curved. These were used to stab into the throat and lower neck of prey, as well to slice into the muscle after a kill had been made. The modified lower jaws of *Dinictis* could open to a wide gape. The animal also possessed very strong neck muscles.

Hesperocyon was one of the earliest members of the Canidae, or dog, family. Its appearance, however, was more like that of a meerkat, a living mongoose. Small, active, and weasel-like, it had a slender body about two feet (60 cm) in length, short, weak legs, five-toed feet, and a long tail. It was a carnivore, with meat-cutting teeth similar to a modern dog's.

Daphoenus was another predator and a member of the primitive carnivorous group called bear-dogs. It was a lightly built animal about three feet (90 cm) long—akin to a greyhound dog. It had a long tail, long limbs, and a badger-like skull with crushing molar teeth and well-developed carnassial (cheek) teeth. *Daphoenus* was one of the main hunters of the abundant game present in North Dakota during the Oligocene. It has been suggested that *Daphoenus* may be an ancestor of the present-day wolf.

Hyaenodon was a member of the primitive and extinct group of flesh-eating mammals called creodonts. Creodonts had huge heads compared to the size of their bodies. Their posterior carnassial teeth were modified to form specialized shearing surfaces for eating flesh. The four-foot (1.2 m) long *Hyaenodon* had long legs, suggesting that it could



***Hesperocyon*, an early member of the Canidae (dog) family, looked more like a meerkat, a living mongoose. About two feet (60 cm) long, it was a carnivore, with meat-cutting teeth similar to a modern dog's. Skull and lower jaw of *Hesperocyon*, Brule Formation, Oligocene, Stark County, length 85 mm.** MM V-1770, V-1771

Courtesy of Marshall Editions Ltd.

Skull of the doglike mammal *Daphoenus*, Brule Formation, Oligocene, Stark County, length 120 mm. ND 282.7

Courtesy of Marshall Editions Ltd.

***Hyaenodon* was probably an active hunter and also a scavenger, like the living hyena. *Hyaenodon* skull, Brule Formation, Stark County, length 310 mm.** ND 02-28.3

Leptictis **skull, Brule Formation, Stark County, length 60 mm.** NDSU

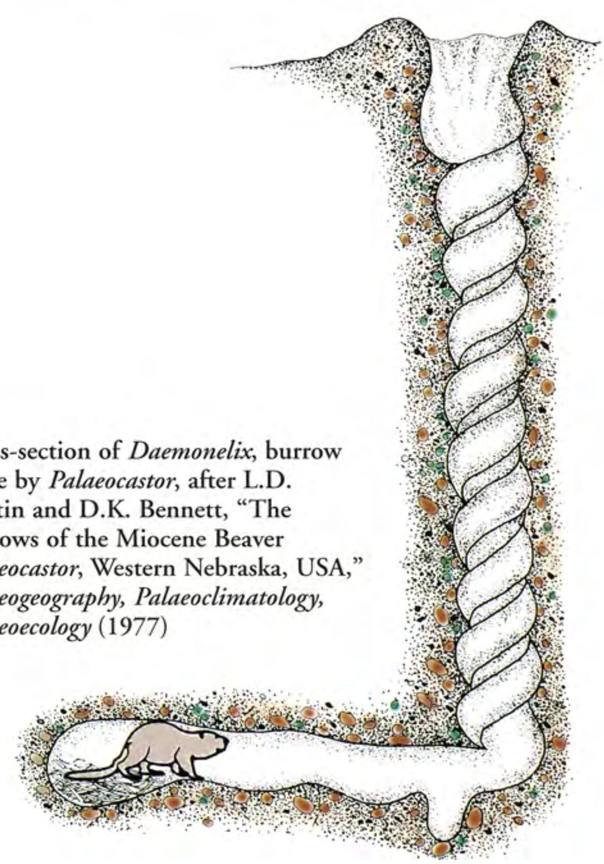
Skull of the oreodont ***Merychyus*****, Arikaree Formation, Dunn County, length 120 mm.** ND 93-93

run, but probably not fast because of its spreading toes. Its strong canines, large premolars, and shearing carnassial teeth indicate that the animal was probably an active hunter and also a scavenger, like the living hyena.

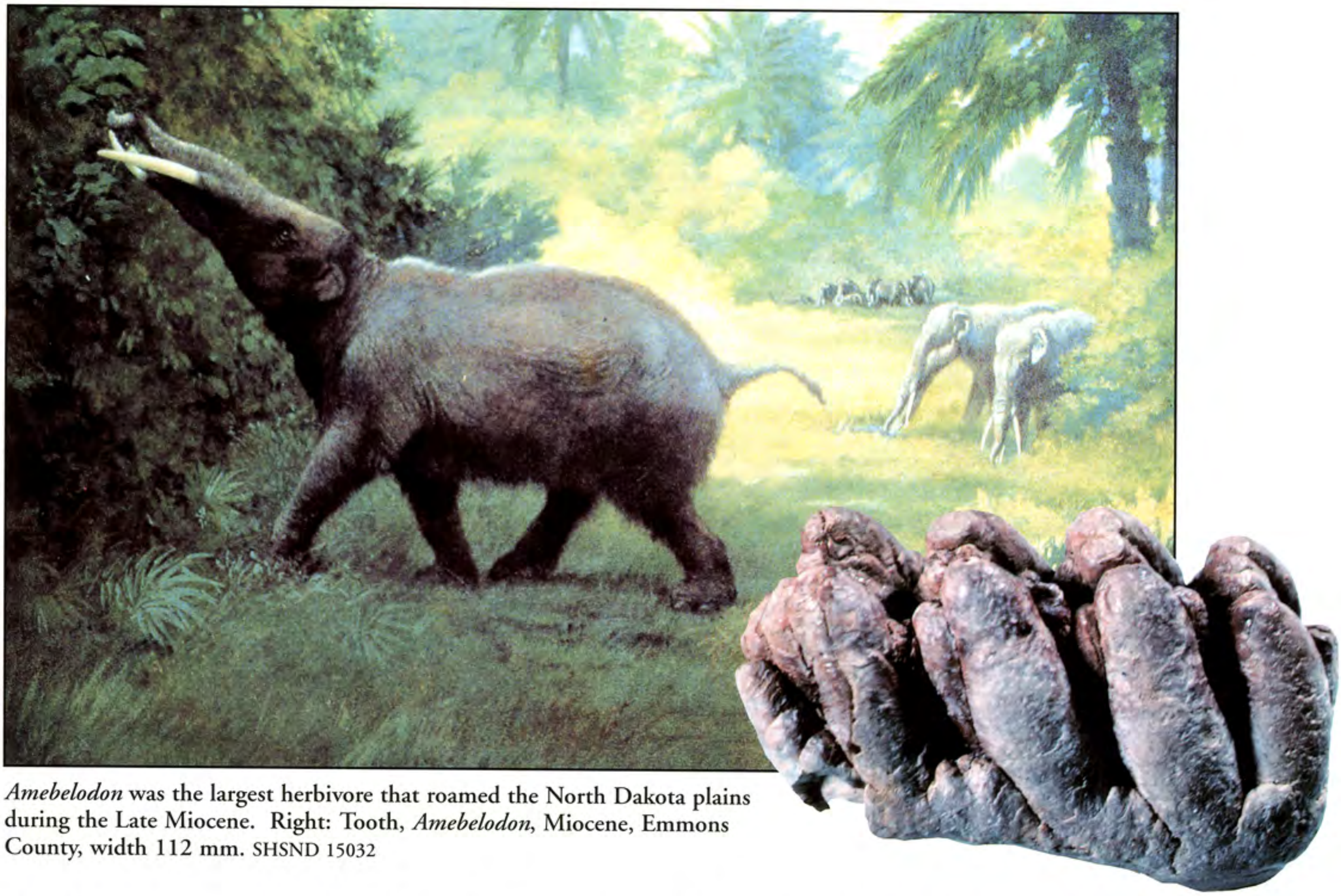
Insectivores were common on the North Dakota Oligocene plain. Well-preserved skulls of *Leptictis*, an insect-eating mammal distantly related to modern shrews, have also been found in the Brule Formation. Its cheek teeth had high, pointed cusps ideally suited for eating insects and other small animals. Like most insectivores, *Leptictis* was a small creature, about a foot (30 cm) in length. It had a long snout similar to that of the hairy hedgehog which lives in Southeast Asia today.

By the late Oligocene and early Miocene (about twenty-five million years ago) the climate had cooled still further, and North Dakota and other areas of the High Plains had become more arid. This climate cooling caused extensive glaciation in Antarctica.[77] Open grasslands with riparian forests, similar to African savannas today, were established in the state by the Miocene. Average annual rainfall was only around fourteen to eighteen inches (35-45 cm), about what it is in western North Dakota today.[78] Little is known about life in North Dakota during this cool, dry period because most of the rocks that would have been deposited then, along with the fossils entombed therein, have been removed by erosion. Also, land mammal diversity in the mid-continent was then at an all-time low.[79] Remains of a few grassland mammals, including the oreodont *Merychyus*, the horse *Miohippus*, and the unusual burrowing beaver *Palaeocastor*, have been found in the remnant Miocene-age rocks.[80] *Palaeocastor* is one of the earliest known beavers. Unlike today's aquatic beaver, *Palaeocastor* was terrestrial. It was about a foot (30 cm) long—the size of a muskrat. It excavated and lived in two-foot-long (60 cm) corkscrew-

Skull of the beaver ***Palaeocastor*****, Arikaree Formation, Stark County, width 50 mm.** UND



Cross-section of ***Daemonelix*****, burrow made by** ***Palaeocastor*****, after L.D. Martin and D.K. Bennett, "The Burrows of the Miocene Beaver** ***Palaeocastor*****, Western Nebraska, USA,"** ***Palaeogeography, Palaeoclimatology, Palaeoecology*** **(1977)**



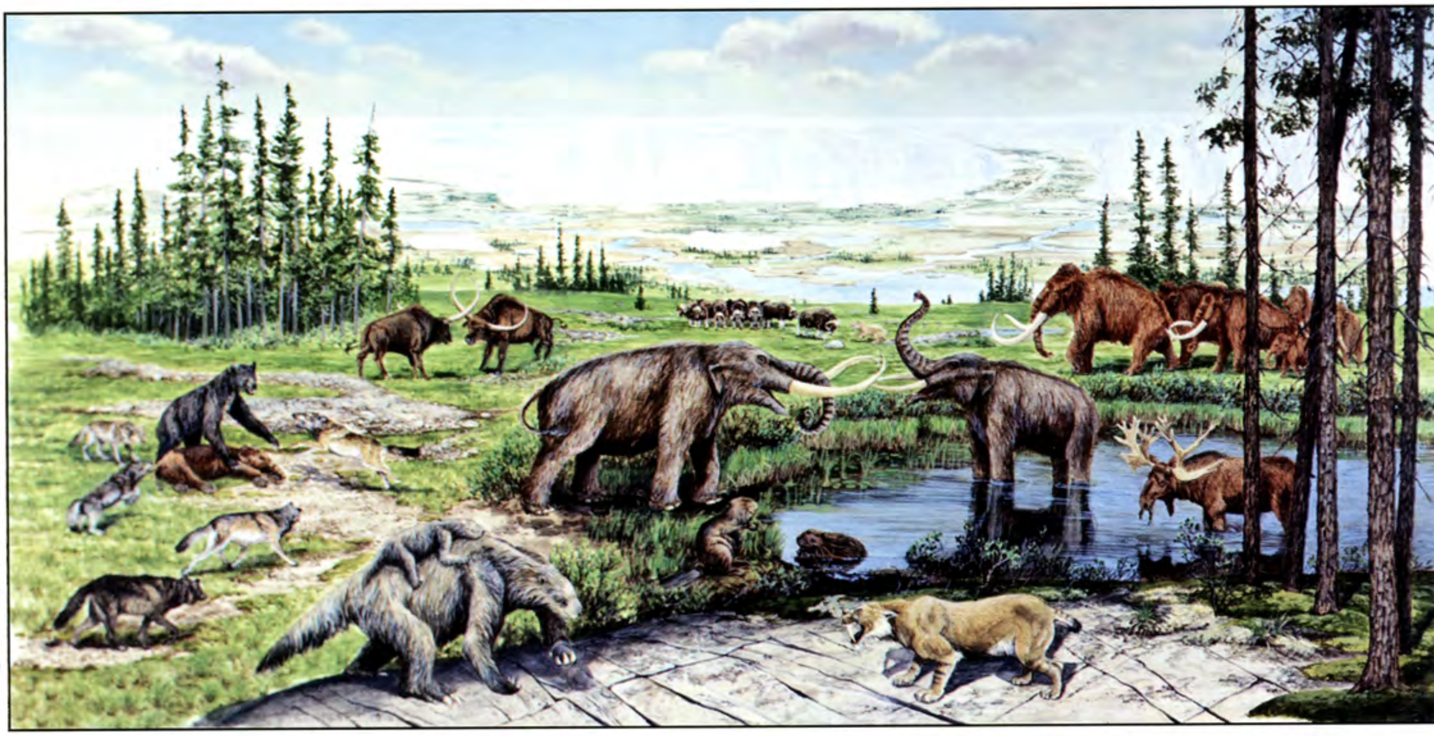
Painting by Charles R. Knight, courtesy of the American Museum of Natural History

***Amebelodon* was the largest herbivore that roamed the North Dakota plains during the Late Miocene. Right: Tooth, *Amebelodon*, Miocene, Emmons County, width 112 mm.** SHSND 15032

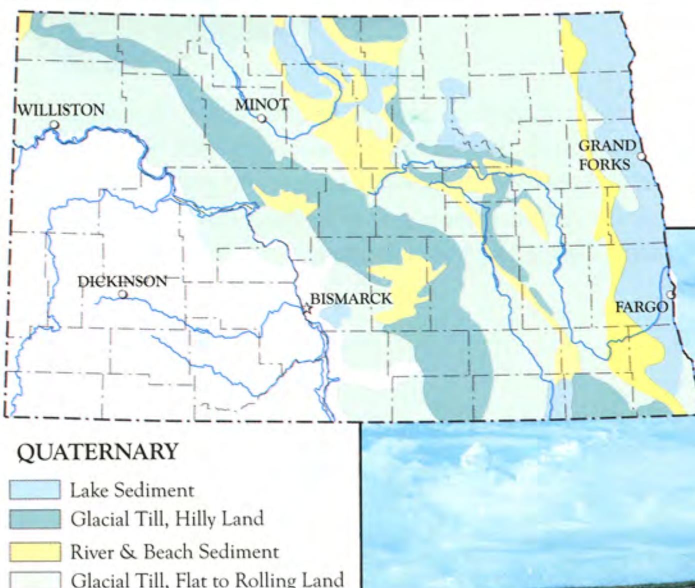
shaped burrows. Scratch marks on the walls of these burrows indicate that the beavers dug them by scraping with their teeth. The helical-shaped burrows are preserved as trace fossils and are called 'Devil's corkscrews'; their scientific name is *Daemonelix*.

There is almost no record of prehistoric life in North Dakota from about twenty million years ago (most of the Miocene and all of the Pliocene) until about fifty thousand years ago, during the Pleistocene. Rocks deposited during that time, and the fossils that would have been found inside them, have also been removed by millennia of erosion. This was a time of global climatic flux, from warm conditions in the early Miocene to cooling in the middle part of that epoch, when glaciation again occurred in Antarctica and the modern East Antarctic ice sheet began to form.[81] Isolated fossils which are occasionally found in North Dakota provide tantalizing hints of what life was like during this mysterious time. One of these finds is the tooth of the "shovel-tusked" gomphothere *Amebelodon*. Gomphotheres were elephant-like animals that migrated to North America from Eurasia across the Bering land bridge during the Miocene, about 16.5 million years ago. *Amebelodon* was about ten feet (3 m) tall at the shoulder and resembled a modern elephant. The skull and tusks of *Amebelodon*, however, were quite different from those of the living elephant. Three-foot-long (90 cm) flattened, spade-like tusks projected from its lower jaws. These flattened tusks would have been used like shovels to dig up rooted water plants in rivers and ponds. *Amebelodon* was the largest herbivore that roamed the North Dakota plains during the Late Miocene.

THE GREAT ICE AGE



Painting by Betsy Thorsteinson, courtesy of The Manitoba Museum



Map by Brian R. Austin

Above: North Dakota's Ice Age landscape resembled the one depicted in this painting. Left: Map showing extent of glacial deposits in North Dakota. Below: Glacial till overlying the Sentinel Butte Formation, shore of Lake Sakakawea near Sakakawea State Park, Mercer County.

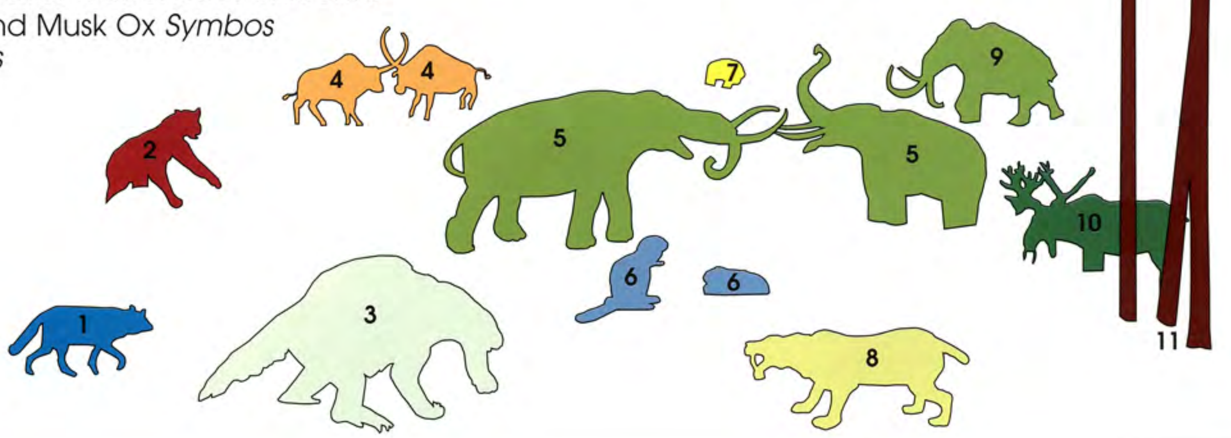
Photo by John Hoganson

Twenty thousand years ago, during the Wisconsinan, most of North Dakota was covered by glaciers.

The last Great Ice Age, during the Pleistocene Epoch, began about 1.8 million years ago, although climate cooling and the development of ice caps at both poles had commenced at the end of the Pliocene, about 3.5 million years ago.[82] It was a harsh time in North Dakota, as the geology and life of the state were dramatically affected by the climate and events associated with glaciation. Glaciers, some several hundred feet thick, advanced into North Dakota from Canada on numerous occasions during the colder times. (Worldwide temperatures were about 8-10°F cooler during times of glacial advance than in the interglacial periods.) Ice sheets extended as far south as the present Missouri River Valley during the last of the major glacial incursions, called the Wisconsinan glaciation, about twenty thousand years ago. During earlier times glaciers had moved even farther south. At glacial maximum the center of the North American ice sheet in Canada was about two miles (over 3 km) thick, and global sea levels were about four hundred feet (120 m) lower than today because of the huge amount of water frozen as glacial ice. These glaciers altered river courses and molded the landscape, creating the gently rolling, hilly topography seen in most areas of the state today. Tundra and northern spruce forests habitats, like those in northern Canada today, developed in front of the glaciers. When the glaciers melted, the sediment incorporated in the ice, called "glacial till," was deposited on the land surface; flowing water from the glaciers also deposited outwash sands and gravels. The northeastern three-fourths of North Dakota is veneered with glacial deposits, in some areas more than four hundred feet (120 m) thick. Fossils of the cold-adapted animals and plants that

Ice Age Landscape Mural Key

1. Dire Wolf *Canis dirus*
2. Short-faced Bear *Arctodus simus*
3. Jefferson's Ground Sloth *Megalonyx jeffersonii*
4. Giant Bison *Bison latifrons*
5. American Mastodon *Mammut americanum*
6. Giant Beaver *Castoroides ohioensis*
7. Woodland Musk Ox *Symbos cavifrons*
8. Saber-toothed Cat *Smilodon*
9. Woolly Mammoth *Mammuthus primigenius*
10. Stag Moose *Cervalces scotti*
11. Spruce Tree *Picea glauca*



Key by Robin Pursley

lived in the state during the Pleistocene are found in these glacial deposits. The most impressive of them were the large mammals, including mammoths, mastodons, giant bison, ground sloths, and horses.[83] Most of these large mammals became extinct at the end of the Pleistocene, about eleven to ten thousand years ago.

Fossils of woolly mammoths (*Mammuthus primigenius*, a migrant from Eurasia across the Bering land bridge), particularly teeth, are fairly common in North Dakota, and fossils of the larger Columbian mammoth (*Mammuthus columbi*) have also been found here.[84] Complete skeletons of either animal have so far eluded discovery in the state. Woolly mammoths are in the same family as modern elephants. They were relatively small for a mammoth, growing to heights of about nine feet (almost 3 m). As with today's elephants, their upper incisors were greatly elongated to form tusks. These recurved tusks were used for brushing away snow, digging up roots, debarking trees, and fighting. Finger-like projections on the end of their trunks were used for grasping. Woolly mammoths were grass eaters, and their huge, flattened teeth were adapted for grinding vegetation. They had a thick coat of shaggy, black-to-brown hair for insulation against the severe Ice Age climate, as well as an undercoat of fine hair and a layer of fat to help stay warm. Much is known about the anatomy of woolly mammoths because frozen carcasses of these animals have been found in Siberia. Early people hunted them for food and clothing; in Siberia dwellings were constructed from their bones, and painted and etched images of them are found on cave walls in France and Spain. They became extinct about ten thousand years ago, at the end of the Pleistocene Epoch, except for a small group of dwarf mammoths that survived on an Arctic island until about six thousand years ago.

The American mastodon, *Mammut americanum*, was one of the most common proboscideans that lived in North America at the end of the Pleistocene, but few fossils of these animals have been found in North Dakota.[85] Unlike the woolly mammoth, a recent migrant from Eurasia, the mastodon had been a resident of North America for millions of years. Mastodons were elephant-like and elephant-sized—about as large as the Indian elephant that lives today—but they were neither true elephants nor very closely related to mammoths. Adults were about ten feet (3 m) tall at the shoulder. The heads of these animals were long and held low, with long, curved tusks. They probably used their tusks to break branches and bark from trees. Because one tusk is usually shorter than the other from wear, it can be determined if the animal had a right- or left-tusk preference. Like the woolly mammoth that lived in North Dakota at the same time, mastodons were covered with long, shaggy hair for insulation against the Ice Age cold. Mummified specimens indicate that they had coarse, brownish outer hair, with a fine woolly undercoat similar to that of semi-aquatic animals such as moose. They were browsers and lived in boggy spruce woodlands. Stomach contents found with mummified mastodon skeletons indicate that they ate a variety of plants, including parts of conifer trees, leaves of various kinds, grasses, bog plants, and mosses. As with the mammoths,

Painting by and courtesy of Dorothy S. Norton

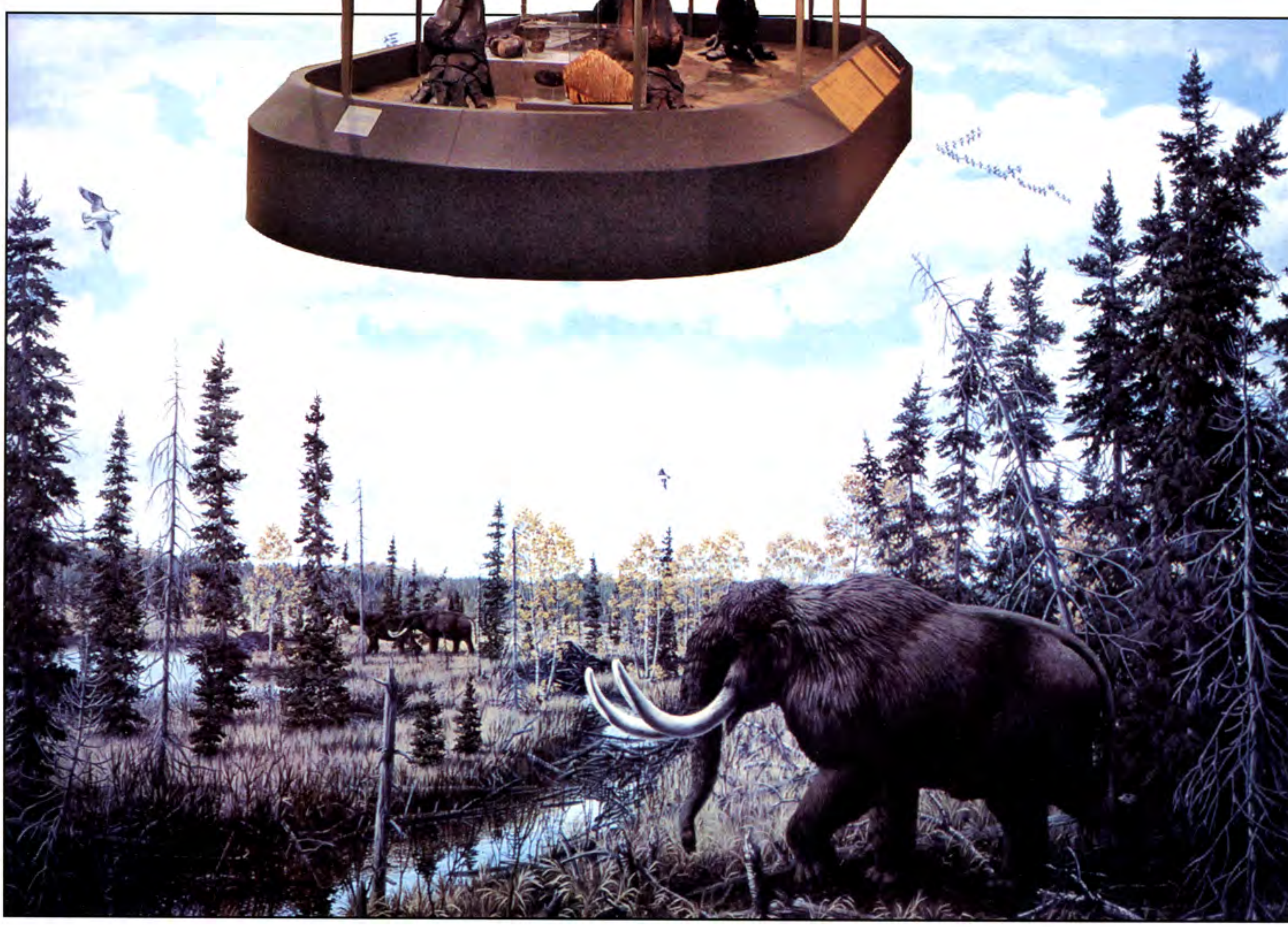
Woolly mammoths, *Mammuthus primigenius*, were relatively small for mammoths, about nine feet (almost 3 m) tall, with a thick coat of hair. They were grass eaters, and their huge, flattened teeth were adapted for grinding vegetation.

Left: This woolly mammoth tooth is about eleven thousand years old. The root of the tooth is at the bottom. Oliver County, width 332 mm.
SHSND 91.0158

Paleo-Indians hunted these animals. Mastodons became extinct at about the same time as woolly mammoths, about ten thousand years ago.

Bison migrated to North America from Eurasia about three hundred thousand years ago, during the Pleistocene.[86] The scientific name of the giant Ice Age bison, *Bison latifrons,* is derived from Greek and refers to this animal's broad cranium and large horns. They were massive animals, the largest of all North American bison, with horns that spanned over seven feet (2 m)—more than twice as wide as those of the living North American bison. *Bison latifrons* bodies were about 25 percent larger than those of their living relatives. Interestingly, some of the early dinosaur hunters initially thought that horns from ceratopsid (horned) dinosaurs were the horns of large extinct bison. Unlike the grassland-dwelling modern bison, *Bison latifrons* lived in small groups and inhabited wooded areas.[87] They became extinct several thousand years ago. Only one fossil skull of *Bison latrifrons* has ever been found in North Dakota—a fifty-thousand-year-old specimen discovered in a glacial

Below: Painting of mastodons in a spruce-aspen forest. Much of North Dakota appeared like this about eleven thousand years ago. Right: Skeleton of the Highgate Mastodon on display at the North Dakota Heritage Center; the skeleton is ten feet (3 m) tall at the shoulder. SHSND 88.240



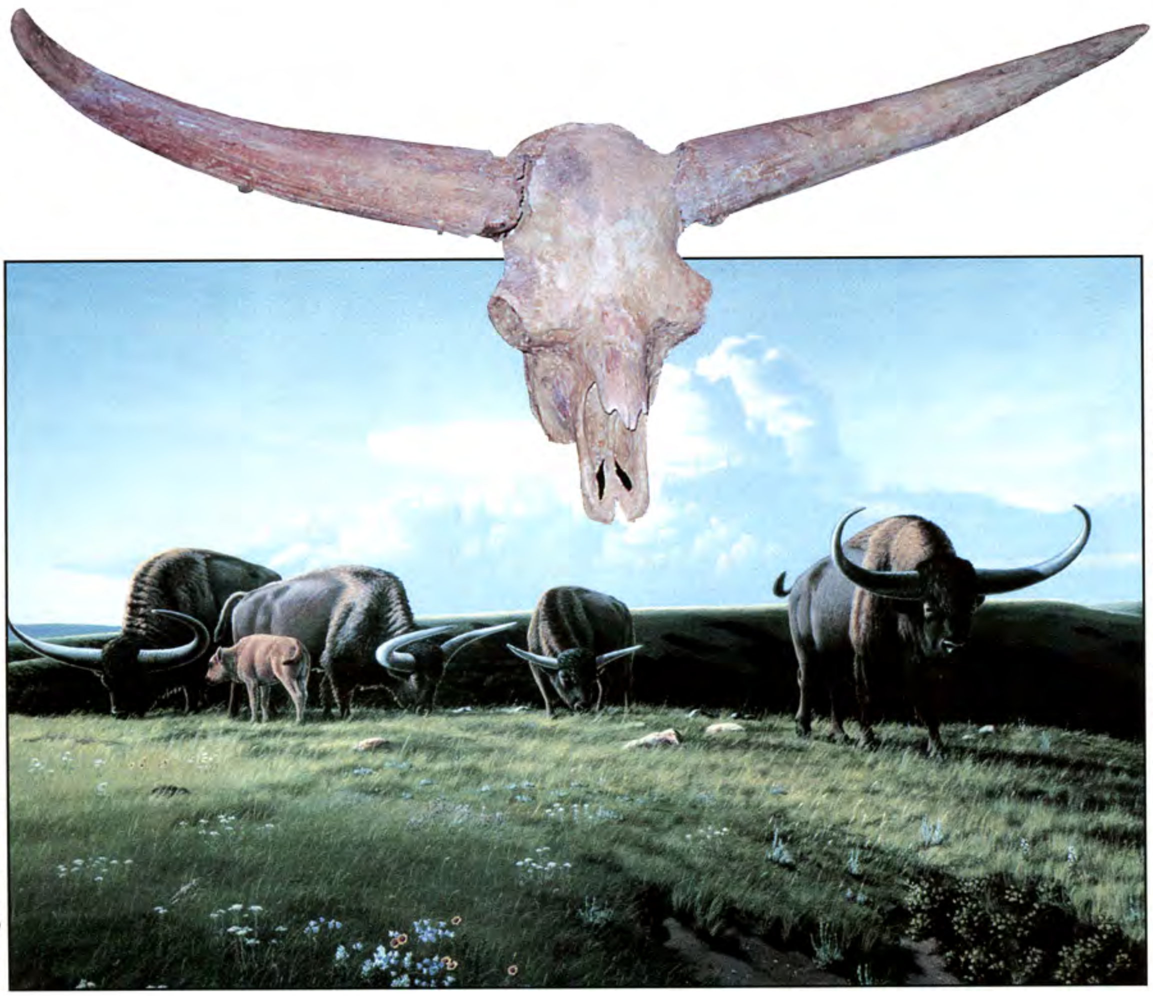
Painting by Robert G. Larson, courtesy of the Illinois State Museum outwash channel.[88]

Ground sloths, emigrants from South America, were also members of the North Dakota Pleistocene mammal community, as indicated by a fossil of the giant sloth *Megalonyx jeffersonii.* The name *Megalonyx jeffersonii*, or Jefferson's ground sloth, is also derived from Greek and refers to the large claw on the third digit of each of the animal's hind feet. Thomas Jefferson, a paleontologist amongst other things, gave the name *Megalonyx* to these giant ground sloths in a 1797 presentation to the American Philosophical Society.[89] It was later given the name *Megalonyx jeffersonii* in his honor. *Megalonyx jeffersonii* was a bear-sized ground sloth that sometimes grew more than six feet (2 m) long. It lived in North Dakota about twelve thousand years ago and was widespread in North America during that time.[90] It became extinct with many of the other large Ice Age mammals at the end of the Pleistocene.

The Ice Age horse was very similar to today's horse and, like its modern counterpart, is also called *Equus.* Contrary to what many people believe, horses lived in North America, and in North Dakota, for that matter, long before they were brought to this continent by the

Painting by and courtesy of Dan Varner

Giant ground sloth, *Megalonyx jeffersonii.* This claw is the first fossil of *Megalonyx* found in North Dakota. It was discovered south of Bismarck in 2000 by Linda and Doug Vannurden. Almost two centuries before its discovery, the Lewis and Clark Expedition, which had been specifically instructed by President Jefferson to look for fossils, passed by the spot on what is now U.S. Army Corps of Engineers-administered land where the fossil was found. Width 165 mm. ND 00-10.1



Painting by Fred Lahrman, courtesy of the Royal Saskatchewan Museum, Regina

Although here shown on the open prairie, *Bison latifrons* would have inhabited wooded areas in North Dakota south of the glacial front. Left: This specimen, the only *Bison latifrons* skull ever found in North Dakota, was discovered by Kent Pelton on U.S. Army Corps of Engineers-administered land within the Fort Berthold Reservation near New Town. Radiocarbon dating indicates that it is over 47,500 years old. Width 2.2 m. ND 98-44.1

Painting by and courtesy of Dorothy S. Norton

Horses like this Ice Age *Equus* ranged across North Dakota thousands of years ago. Above: These *Equus* foot bones are about fifty thousand years old and were found in McKenzie County in an Ice Age river channel on land administered by the U.S. Army Corps of Engineers within the Fort Berthold Reservation. Length 109 mm. ND 63-2

Spaniards. In fact, horses first evolved in North America. Fossils of "*Hyracotherium*" recovered from the Golden Valley Formation indicate that horses have lived in North Dakota since the Eocene, about fifty million years ago.[91] Remains of *Equus*, meanwhile, have also been found here in Pleistocene deposits that are about fifty thousand years old.[92] Like today's horse, the Ice Age horse had one toe on each foot and high-crowned teeth adapted for eating grasses. Horses were wide-ranging during the Pleistocene in North America, but became extinct on this continent at about the same time as many of the other large Ice Age mammals. Why they became extinct in North America and not in the Old World is a matter of debate. The horse was reintroduced to this continent by the Spanish conquistadors when they arrived in the southwestern part of what is now the United States in the 1500s. The Mandans in North Dakota apparently had acquired horses by about 1750.

Unfortunately, fossils of large Pleistocene carnivores like the famous saber-toothed cat, *Smilodon fatalis*, or the dire wolf, *Canis dirus*, have yet to be found in North Dakota.

After about twenty thousand years ago—the last glacial maximum in North Dakota—the climate began to warm and glaciers began to melt; spruce-aspen forests became established south of the glacial ice.[93] The climate was still cool and moist, however. Ponds and bogs existed in these forests. Fossils found in pond and bog sediments dating to about eleven thousand years ago indicate that cold-adapted

Beaver scat
(wood chips visible)
Castor canadensis
11,000 years old
Stutsman County
Width 16 mm
ND 07-73.13

Spruce cone
Picea glauca
About 11,000 years old
Sheridan County
Height 33 mm
UND 14256

Aspen leaf
Populus
About 11,000 years old
Sheridan County
Length 102 mm
UND 14279

Glacial meltwater created many ponds and bogs that were inhabited by cold-adapted species, including frogs, fish, insects, mollusks, and small mammals. All fossils illustrated below are about eleven thousand years old.

Muskrat skull
Ondatra zibethicus
Stutsman County
Width 24 mm
UND 13901

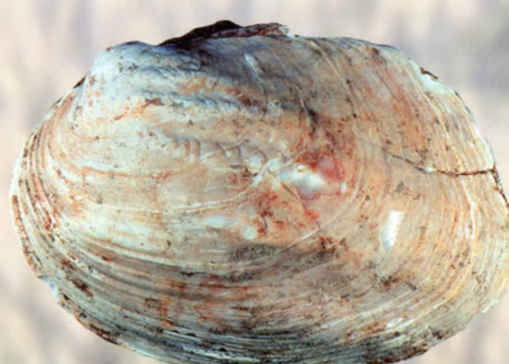
Damselfly
Sheridan County
Length 24 mm
UND A-2371

Yellow Perch
Perca flavescens
Sheridan County
Length 175 mm
UND

Leopard frog
Rana pipiens
Stutsman County
Length 78 mm
UND 13015

Ground beetle
Sheridan County
Length 26 mm
UND 14280

Gastropods
Lymnaea (high spired)
Helisoma (coiled)
Stutsman County
Height 32 mm (*Lymnaea*)
NDSU

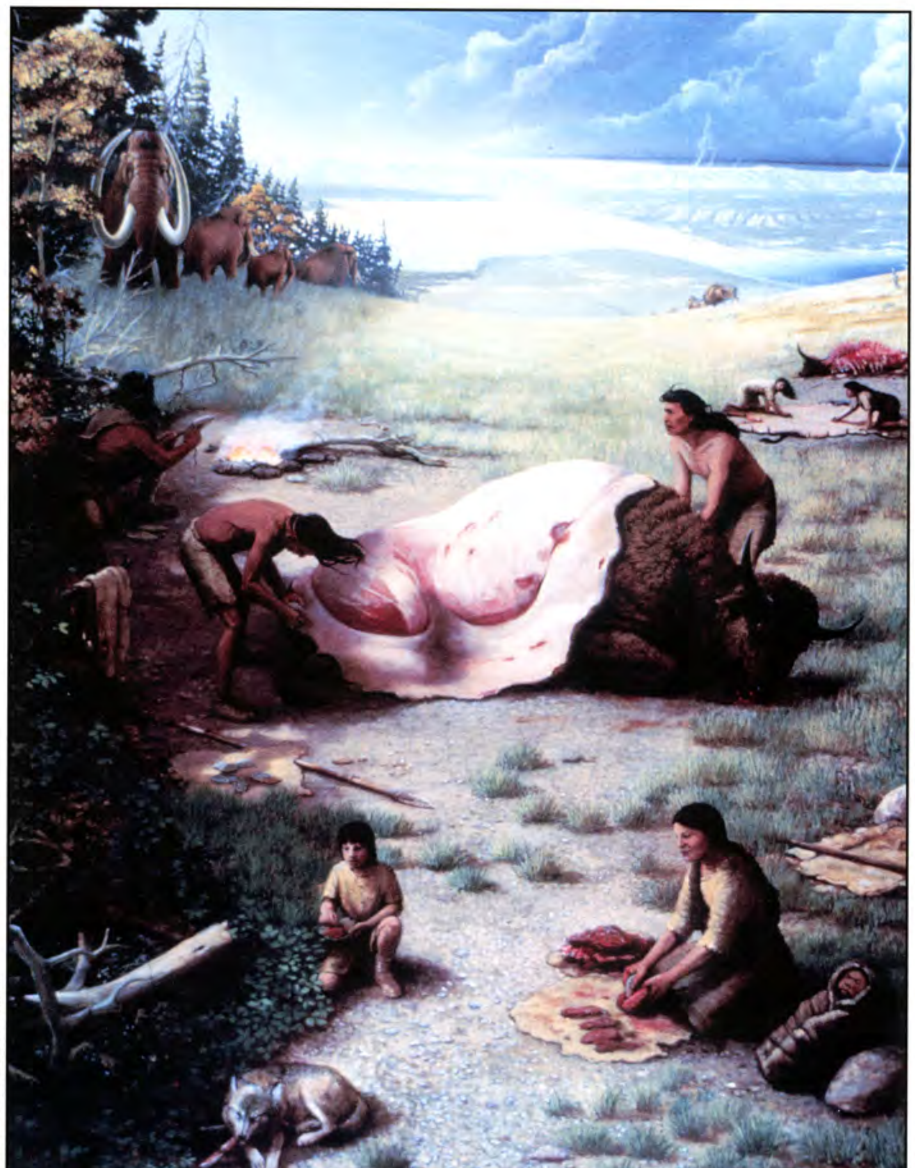


Clam
Amblema plicata
Richland County
Width 109 mm
UND A3017

frogs, fish, insects, crustaceans, mollusks, plants, and small mammals, including beavers and muskrats, inhabited North Dakota.[94] Great volumes of meltwater entered the drainage systems, creating large channels across North Dakota, and glacial Lake Agassiz formed in what is now the Red River Valley as the ice margin retreated into Canada. At its maximum, this lake was about three hundred feet (90 m) deep near present-day Fargo, and more than one hundred (30 m) feet of lake sediment was deposited in most areas of the valley. These nutrient-rich sediments now constitute some of the flattest and richest farmland in the world. Lake Agassiz occupied portions of eastern North Dakota until about eight thousand years ago.[95]

Artifacts in glacial sediments indicate that the first people to reside in North Dakota were here by eleven thousand years ago. They were big-game hunters, preying on mammoths and other large mammals, as well as gatherers of wild edible plants. Nearly all of the large Pleistocene mammals—thirty-two species, including mammoths, mastodons, horses, and camels—became extinct in North America between about eleven thousand and nine thousand years ago.[96] Only the medium-sized (bison, deer, pronghorns) and smaller mammals survived.

The possible cause or causes of the extinction of the large mammal populations has been debated for decades. One of the most controversial theories, termed the "overkill hypothesis," suggests that they were hunted to extinction by humans.[97] Others argue that the large mammals became extinct because they could not adapt to the rapid climate warming and resulting habitat changes that occurred at the end of the Pleistocene.[98] It is likely that hunting by humans, drastic climate change, and perhaps other factors all played roles in driving the large Pleistocene mammals to extinction.[99] Whatever the reasons for this extinction, most of the large mammals of the Pleistocene world were gone by the beginning of the Holocene, ten thousand years ago.


Pembina State Museum

Paleo-Indians butchering a bison at the end of the Ice Age.

THE HOLOCENE: A REPRIEVE FROM THE ICE AGE

Although massive ice sheets still exist at both poles and Earth has not returned to the glory days when tropical to subtropical conditions existed worldwide, global climate has warmed dramatically since the coldest glacial intervals during the Pleistocene. This warming trend ushered in the Holocene Epoch, which began ten thousand years ago and continues to this day.

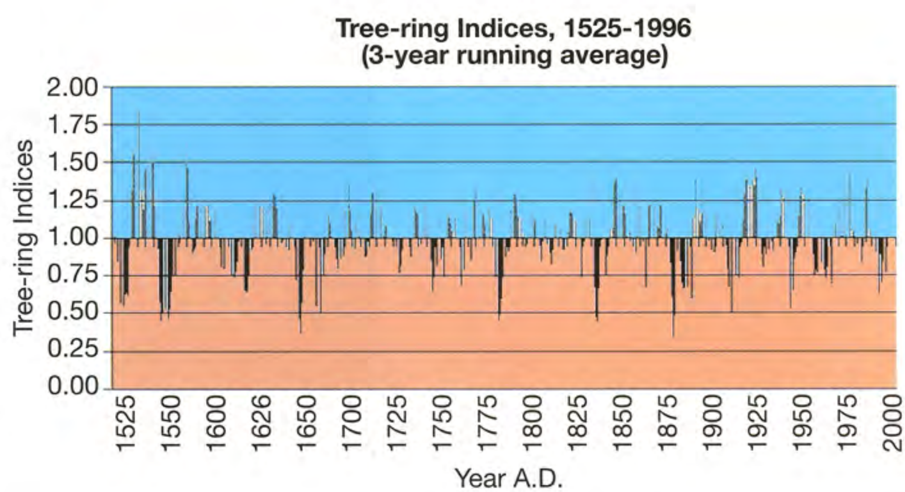
Between about nine thousand and seven thousand years ago, as the climate warmed and became drier, prairie habitats became established in North Dakota.[100] It was during this time that plants and animals that live in the state today began colonizing the area. But climate was still in a state of flux. Pollen fossils from lake sediments indicate that prairie ecosystems were drastically affected by intense drought conditions between about eight thousand and four thousand years ago.[101] Fluctuations in climate influence life on the North Dakota prairie even today, as current drought conditions show.

Study of the history of life in North Dakota based on the fossil record mostly ends at the point when prairie ecosystems became established, although "recent" fossils are occasionally unearthed, providing insights about life here during historic times. The remains of bison and elk, which lived here in vast herds when Native Peoples were the only human residents and when Lewis and Clark passed through here two hundred years ago, are an example. These recent fossils corroborate knowledge of life in the state based on oral and written accounts. Perturbations in climate during historic times can also be detected from fossils, particularly those found in lake, pond, or bog sediments.

The ever-changing story of life in North Dakota continues today with the introduction of new plant and animal species, the loss of old ones, and adjustments to the ranges of those that have lived here for hundreds of thousands of years. This story is now being deciphered by botanists, zoologists, and ecologists.

SHSND 1983.403

One of the methods by which scientists can determine how climate has changed in recent times is through analysis of tree rings. The age of a tree can be determined by counting its annual growth rings; this is called dendrochronology. Measurements of the width of the tree rings can also reveal annual changes in precipitation rates; this is termed dendroclimatology. An early attempt to determine wet and dry years in North Dakota using this approach was made in the 1940s by George F. Will, using this tree slab from a bur oak cut down near Bismarck in 1940, as well as other trees and logs from prehistoric Indian dwellings.



Using modern techniques, M.A. Gonzalez reconstructed a 470-year-long tree-ring precipitation record for western North Dakota, based on Ponderosa pines (*Pinus ponderosa*) from Slope County.[102] In his graph, tree-ring indices of 1.0 indicate near-normal precipitation, and indices below 1.0 (red) are times of drought. Note that droughts at least as severe as the 1930s Dust Bowl years have occurred about twice per century. As can be seen on this graph, the driest three-year interval in the past 470 years in southwestern North Dakota was from 1863 to 1865.

EPILOGUE

I suppose it is presumptuous to think that the story of life in North Dakota, which covers about five hundred million years, can be adequately told in a short essay like this. Even though the story is sketchy, the fascinating glimpses of life in North Dakota's prehistoric past outlined here are based on solid paleontological evidence resulting from the many spectacular and well-studied fossil sites found in the state. The tropical greenhouse conditions of the Paleocene, when crocodiles inhabited North Dakota, and the tundra icehouse conditions of the Pleistocene, when woolly mammoths roamed the state, are extreme ends of the spectrum of continual change through time in the life and climate of this place as revealed by the fossil record. This record gives us a perspective on how transient and fragile life and climate are in a changing world. The more we study and understand the past, the more meaning the present has, and the knowledge that we gain through these studies provides a basis for predicting future climatic and biological changes.

Information about ancient plant and animal communities and the environmental and climatic conditions in which they lived is particularly important today because of human influence on our own climate and environment. Paleontological studies in North Dakota have shown that life has been drastically altered in this state on several occasions by naturally occurring changes in climate. Scientists now assess and evaluate on a daily basis how natural climate cycles are being influenced by humans, and baseline data from prehistoric fossil records can be used to assist in those assessments. The study of fossils has also revealed the devastating effect mass extinctions have had on life in North Dakota.

Today, it has been estimated that a startling thirty thousand species (a conservative figure) of plants and animals worldwide are driven to extinction each year, mostly through habitat loss caused by humans.[103] This ongoing loss will ultimately be viewed as one of the most devastating extinction events ever recorded. Richard Leakey and Roger Lewin have already termed it the "sixth extinction," in reference to the five other instances of major mass extinction—for example, the K/T boundary extinction event of 65 million years ago—that have occurred over the past 450 million years. Let us hope *Homo sapiens* ("wise man") will be wise enough to live up to our namesake and curtail this current global biological catastrophe.

The study of paleontology gives us a perspective on how transient and fragile life and climate are in a changing world. This flower, found in the Sentinel Butte Formation, Morton County, is sixty million years old. It thrived in a lush, humid, swampy landscape, much like that of today's Florida Everglades. Width 6 mm. ND 388.18

From West Fargo, North Dakota, **John Hoganson** is the paleontologist for the North Dakota Geological Survey and the curator of the State Fossil Collection at the North Dakota Heritage Center. He graduated from North Dakota State University with a degree in Earth Science. He then obtained a master's degree in geology from the University of Florida and a doctorate in geology from the University of North Dakota. Both graduate degrees emphasized paleontology. John has authored numerous scientific and popular articles and chapters in books about North Dakota geology and paleontology. In 2003 he coauthored a book with Ed Murphy titled *Geology of the Lewis and Clark Trail in North Dakota.* In 1993 he received the Governor's Award for Excellence in Public Service and in 2001 was honored as a master alumnus by the College of Science and Mathematics at North Dakota State University. John has been with the North Dakota Geological Survey for twenty-five years.

ACKNOWLEDGEMENTS

This article is a brief summary of our knowledge of the prehistoric life of North Dakota based on studies by many past and present researchers. It would not have been possible for me to write this essay without their work, which I have liberally cited. Images by artists who specialize in bringing to life prehistoric animals and habitats have always fascinated me, and I would like to thank Dan Varner, John Sibbick, Dorothy Norton, and Richard Ellis, as well as a number of other artists and institutions, for graciously allowing use of their paintings. I also appreciate the fine graphic artwork of Brian Austin and Robin Pursley. Allan Ashworth, friend and mentor, Mike Newbrey, and Brett Woodward provided photographs of many of the fossils illustrated here. Their help is gratefully appreciated. I also want to thank J. Mark Erickson, Ed Murphy, and Cathy Clayton for providing insightful and useful reviews that have markedly improved the article. The first draft of this essay was much different from the one published here because of the hard work by Kathy Davison and Wynne Paasch who provided creative ideas about how to best display the information and greatly improved the text. It has been delightful working with them.

Endnotes

Abbreviations Key

North Dakota Geological Survey	NDGS
Proceedings of the North Dakota Academy of Science	*PNDAS*
Bulletin of American Paleontology	*BAP*
Bulletin of the American Museum of Natural History	*BAMNH*
Peabody Museum of Natural History Yale University Bulletin	*PMNHB*
Journal of Vertebrate Paleontology	*JVP*
Geological Society of America	*GSA*
United States Geological Survey	USGS

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